

Metallurgy

as a
Factor
in the

Progress of Automobile Engineering

THE progress made in automobile engineering during recent years is well emphasised by the display at the Motor Exhibition. Anyone who can recall the products of this industry of twenty or thirty years ago and is able to make comparisons with the exhibits at Olympia will appreciate the remarkable strides that have been made towards the attainment of perfection. In the early days the unreliability of materials at the disposal of the designer and manufacturer created many difficulties, production was comparatively slow and consequently costly, and the cars produced were noisy in action, and as a result of excessive vibration were generally uncomfortable to the user. To-day, as a result of rapid development, the products of the industry are remarkable in their degree of efficiency, durability and comfort at prices covering a wide range but relatively low.

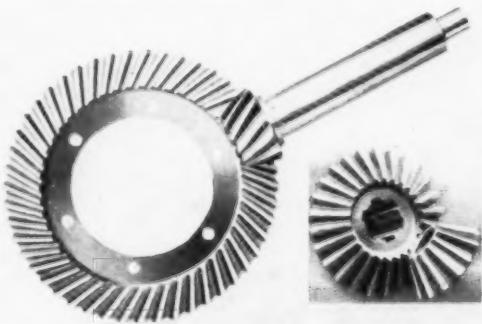
Of the many factors that have contributed to the progress of this industry not the least important is the high standard of reliability attained. The metallurgist has co-operated with the engineer and has supplied metal and alloys to meet service conditions, while the engineer has increased his knowledge of the stresses to which various parts are subjected and designs have been modified, in the light of superior knowledge and improved metal, to carry stresses safely. The technique of production in relation to the material involved, and the finishing and assembling of the parts, have been worked out on more highly developed lines, and to-day production has reached a very high level.

Improvements in the production of steel, together with its fabrication into final forms, have had an important influence on the progress. The increasing use of the electric furnace, in which the refining conditions permit better opportunities for deoxidation and the reduction of non-metallic inclusions, is an outstanding feature in steel production for automobile work. The development of alloy steels, and the heat-treatment to which many are subjected for various purposes, have proved of immeasurable value to the automobile engineer. Considerable advances made in rolling-mill practice, both in regard to hot and cold working, have materially assisted in the general development.

The steels employed may be ordinary carbon steels, or, in addition to a varying percentage of carbon, small percentages of special elements may be included in order to modify or improve their mechanical properties: these are the alloy steels. The very low-carbon steels form the basis from which sheet, frames, tubes, and case-hardened parts are produced. For cylinders, steel of higher carbon contents may be used, and with further carbon the steel is used for rim-wheels and clutch-plates. The value of nickel as an alloying element in steels has long been recognised for certain types of case-hardening work. There is, however, a growing tendency to use nickel steel for the chassis frames in the better types of cars, and in racing cars in

particular. The use of nickel steel or nickel-chromium steel in the properly heat-treated condition gives enhanced properties, which allow reduction in weight or enables the parts to withstand more arduous conditions.

Some special alloys contain tungsten, and have a composition somewhat resembling high-speed steel. Thus, for instance, valves may be of steel, in which a high percentage of tungsten is present. For valves, it is necessary to employ a steel capable of withstanding not only high-temperature scaling conditions and heavy stressing, but also heavy abrasion, and the material used must give satisfactory wearing service in keeping with the high degree of reliability of other parts. Special nickel-chromium-tungsten steels in the ratio of 6-12-2 or 14-28-5 are used for this purpose, as they possess relatively high strength at elevated temperatures, and offer remarkable resistance to scaling. Many steels suitable for hardening and tempering operations can be locally hardened to resist wear, but are unsuitable at higher



Group of Heat-treated Nickel-chrome Rear-axle Gears.

temperatures; on the other hand, with the heat-resisting steels case-hardening cannot be done, so that when making use of the remarkable properties of higher nickel-chromium-tungsten steel for valves it is expedient to fit hardened thimbles over the ends to cope with end wear.

The value of the austenitic nickel-chromium steels for practically all the bright parts cannot be emphasised too strongly. In many cars exhibited at Olympia, windscreens, radiator shells, lamps, ventilators, handles, nut caps and the interior fittings will be found to consist of this nickel-chromium steel, as the usefulness of this material has been proved. Chromium plating forms the protective coating in the case of many cars; the methods more generally adopted for depositing the chromium have long passed their experimental stages, and the parts so protected may be relied upon to maintain their appearance after prolonged service.

There are a number of steels from which to choose for the springs, which have a considerable influence on the running of a car. For this purpose silico-manganese or chromium-vanadium steel give good results. The tempered spring plate should be hard, and yet possess ductility to a considerable degree, and the heat-treatment to which they are subjected should be carried out with extreme care to

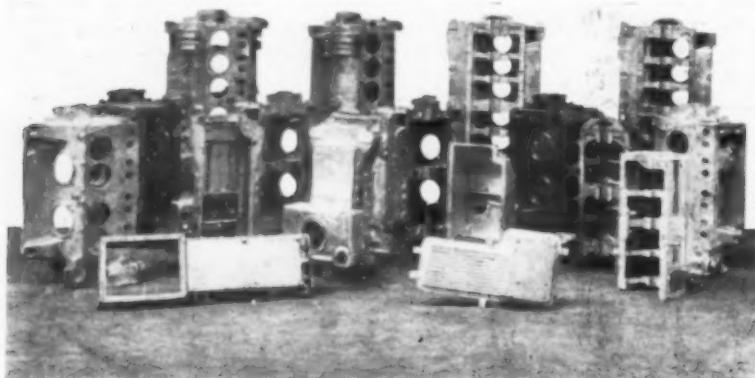


Exhibit of Aluminium Castings by F. H. Adams, Ltd.

preserve these properties. Substantial advances have been made in regard to the proper heat-treatment necessary, and in the manner of checking to maintain consistency in the desired properties.

The front and back axles of cars involve care in the selection of suitable materials. It is true that the breaking of an axle may be due to faulty design or to improper use of the car, rather than wrong material, but care in the choice of materials will reduce the possibility of breakage from any cause. The use of powerful wheel brakes has necessitated the use of axles capable of withstanding the higher stresses resulting. A heat-treated alloy steel is frequently used for the front axle, containing 0.4 carbon with 1% of nickel. The nickel addition assists the steel to respond more readily to heat-treatment, and particularly to more efficient hardening of the whole mass as a result of oil quenching. It is advisable, however, to increase the percentage of nickel when stronger axles are required, and the use of 3% nickel steel or a nickel-chromium steel may be desirable. Stampers are now familiar with the difficulties associated with the stamping of 3% nickel steel, and the additional care it involves. In regard to back axles, the nickel-chromium steel, giving a yield point of 65 tons per sq. in., a maximum strength of 73 tons per sq. in., 19% elongation, and Izod value of 35 ft.-lb., provides the designer with a material which, with reasonable usage, will withstand the strenuous work to which this part is subjected.

In modern design the case-hardened mild-steel gear formerly in common use has been largely supplanted by the alloy-steel gear. Those in more general use are the nickel and nickel-chromium case-hardening steels. The necessity of using a steel of high-core strength is recognised by all makers, and the higher initial cost is more than compensated by the increased reliability of its service. Many of the gears are subjected to very strenuous work, and this is materially increased when the car is driven by an inexperienced or a negligent driver. It is, therefore, necessary to make ample allowance when choosing the material to be used, so that it will possess excellent wearing qualities as well as have the requisite toughness to resist shocks; in addition, the design must be consistent with quiet transmission. The 3% nickel case-hardening is frequently used for this class of work, and a large number of the car manufacturers specify this steel. The heat-treatment of parts in this steel consists in heating to 760° C. and then quenching in oil. Many manufacturers prefer to take advantage of the

greater toughness of a 5% nickel steel, oil quenched, or an air-hardened nickel-chromium steel.

Many proprietary steels applicable to automobile engineering are exhibited, notable of these being "Ubas," "Silkase," and other well-known case-hardening steels of W. T. Flather, Ltd. These are supplied in rolled and drawn bars, in stamping bars, and in forgings.

The cylinder blocks are more commonly in cast iron, a material which gives excellent service, particularly when a small percentage of nickel is added with a suitable silicon content. The increased wearing qualities required from the cylinders as a result of higher working pressures in modern practice is materially assisted by the nickel content in the iron. The use of aluminium alloys is gradually increasing, and the head and crankcase are now frequently made from these alloys. Then much depends upon the piston rings, for which the use of cast iron predominates. A material is required in which practically all the combined carbon present is in the form of pearlite. Excellent piston rings are on view at the Exhibition, known as "Brico" piston

rings, in which the cast iron, in addition to having a pearlitic structure, shows an extremely fine division of the graphite. The castings are made centrifugally, and the British Piston Ring Co. have designed and patented centrifugal casting machines, which are exhibited.

Special aluminium alloys have been developed and used in the cast form during the past few years, and many exhibits, including those of F. J. Adams, Ltd., and the Birmingham Aluminium Casting Co., Ltd., illustrate the wide uses to which these alloys have been applied successfully, not only for motor-cars, but also for motor-boats. The special quality of corrosion resistance has, in many cases, been exhaustively investigated, and alloys of this type have been applied for parts subject to corrosion with complete success. These are film-forming alloys, which derive their power of resistance, under severe conditions, from the formation of a fine, protective film, which arrests further action and avoids the more serious corrosion resulting in pitting and ultimate breakdown of the structure.



Corrosion-resistant Aluminium Alloys by Birmingham Aluminium Casting Co., Ltd.

Quite a wide variety of aluminium alloys are now available for use in the production of general sand or die-castings, special alloys for die-cast pistons, for general forged work, and for forged pistons. In some instances the compositions are of such a character that the products are amenable to heat-treatment, and their physical properties are thus capable of considerable improvement. The new

"Hiduminium" R R series of alloys have this characteristic and have shown marked progress. The series includes R R 59, which is an alloy for sand or die castings for general purposes. It has a high-proof stress, and the general physical properties are remarkably good. Heat-treated castings remain stable, and are not subject to further ageing. The R R 53 is a die-casting material suitable for parts that are to work at an elevated temperature. In the heat-treated condition this alloy gives a very high ultimate strength, and its hardness is also high. These characteristics are retained to advantage at elevated temperatures. The R R 56 is available in the form of forgings or stampings, as extruded bars and sections or as rolled sheets. It has high physical characteristics, and is easily forged and stamped. The R R 59, another of the series, is a counterpart of the R R 53, and is designed as a forging alloy for pistons.

Considerable progress has been made in the development of magnesium alloys, and many castings of this remarkably light alloy are displayed. The castings are homogeneous and reliable, and test-pieces show higher tensile and more

uniform properties than similar test results from aluminium castings.

It has only been possible to refer briefly to the influence of the metallurgist on the motor engineering industry, who, in providing materials of increased reliability, has contributed considerably to its progress and assisted in raising

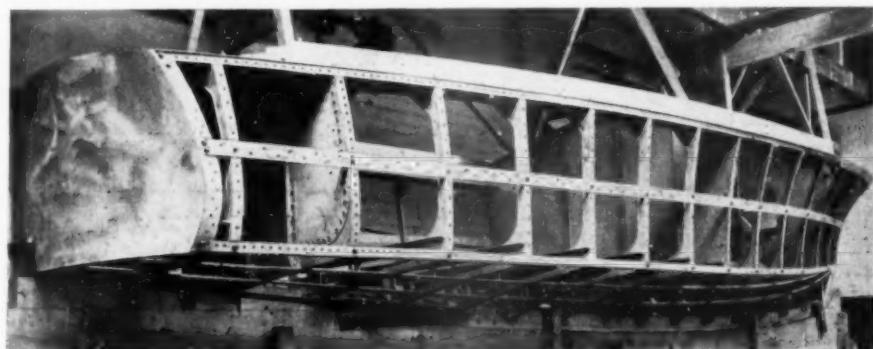


Exhibit showing further uses of Corrosion-resistant Aluminium.

the standard of efficiency to such an extent that it is now one of the most progressive industries, and we are optimistic enough to believe that continued co-operation between the designer and metallurgist will further enhance the reputation of British industry in regard to quality of product and its performance under exacting and strenuous conditions.

The Future Trend of Automobile Design

In an inspiring address delivered before the Institution of Automobile Engineers by the President, Sir Herbert Austin, K.B.E., stated that the future of the automobile must be largely based on the experience gained in the past, but the exigencies of manufacture, particularly since the war, have controlled progress in design more than any other reason, though the rapid improvement of roads and the incidence of our vehicle taxation have, among other causes, been instrumental in holding back progress in the design of vehicles suitable for Colonial use.

Very great progress has been accomplished in making our vehicles safe to operate. It would be an impossible task by any change in design to prevent some careless or reckless driver from taking risks. Shock-absorbers, reliable pneumatic tyres, and steering gears and connections, improved road-holding qualities and suspension, four-wheel efficient brakes, all contribute to make a journey on a present-day road vehicle a thoroughly safe undertaking—quite as safe in effect as any other means of travel.

The cost of operation must, of course, always be largely a matter of speed and weight, but present-day vehicles are wonderfully economical if treated rationally, particularly in the direction of repairs and overhauls. While the cost of operation will always be a governing factor, we have already arrived at results which will require some scheming to improve upon substantially. Future designs must take stock of the following essential points. All transport will keep increasing in pace: all transport, particularly of persons, will improve in riding and driving comfort: all transport will become safer: all transport will be cheaper to purchase and cost less to operate.

Every change in design must follow one or more of these directions to be successful and permanent. No slavish following of one direction at the expense of the rest can hope to be generally acceptable. For instance, increases in speed at the expense of comfort and safety must be

limited to special purposes and the demands of a special type of purchaser. On the other hand, operating cost can only influence speed in a comparative sense, and there is a very well-defined point where the limitation of speed would put up the operating cost, especially of commercial vehicles, quite apart from the influence of other forms of competitive transport.

The relative position of the various units in the chassis is a subject to which a great amount of attention has been and is being given. The present sequence of front-steering axle, engine, clutch, gearbox, propeller shaft and rear axle is universal, but there have been several attempts to make the front wheels take the drive on passenger cars during the last year or two, and with a certain degree of success in one or two instances. The adoption of front-wheel drive admits of a lower chassis and overall height of body, and this might become an important matter if much lower bodies were to be the fashion. The same facilities are, however, obtained by placing the engine at the rear, and this gets rid of a certain amount of difficulty caused by taking the drive through the steering swivels. It also retains the advantage of taking the drive through the rear wheels, which must always have a better tractive adhesion than the front wheels, especially when ascending a hill or getting away from rest.

With the growth of so-called mass production, the narrow outlook and the primitive methods of the old-type carriage builder were brushed on one side, and the body then began to be more of an essential part of the vehicle, but it is still far too much separated and constructed as a thing apart. The result is that the total weight of the vehicle is considerably heavier than it need be, and because of this extra weight of material and the additional work entailed, the cost is also appreciably increased. Now that we are using steel with cellulose painting for the body, there is a big opportunity to design the vehicle from the carriage work end and add the mechanical components to it.

Some Common Defects in Steel for Gear Manufacture.

By Francis W. Rowe, B.Sc. M.I.M.M.

STEEL for the manufacture of gears must, of necessity, be sound and free from small imperfections which in other types of finished product might not prove serious. The constant striving after low weight per horsepower, with the resultant increase in working stresses, has lowered considerably in recent years the factor of safety which allowed steels with slight defects and imperfections to function satisfactorily formerly. It is no uncommon thing nowadays to have working stresses 80 to 85% of those which the steel is capable of standing without failure, and thus any reduction of the normal strength of the steel due to segregates, slag inclusions, non-uniformity, or errors in heat-treatment, quickly leads to trouble in service.

Besides this danger of gears failing in service, there is another factor which renders it highly important that the gear manufacturer should have consistently sound material. On account of the high stresses to which a gear is usually subjected, and this low factor of safety, modern gears must be made with extreme accuracy to ensure each tooth carrying its due proportion of the load, and also to ensure

quiet running. This renders a modern gear initially a rather expensive article, and the gear manufacturer is involved in a heavy loss should defects in the material be revealed at a late stage in manufacture or in service. A forging costing five shillings may be turned into a gear costing six or seven times this amount. Thus, the loss to the gear-maker, if defects are only revealed at a late stage, will be correspondingly six or seven times that to the steel-maker. Every care, therefore, is necessary to ensure that no steel is passed forward for gear-making which has the slightest likelihood of giving trouble in manufacture or service, and anyone connected with gear manufacture has to be doubly careful in this respect.

On the other hand, there is no perfect steel, and a certain amount of discrimination must necessarily be exercised to appreciate which defects are likely to cause trouble in service and which are not. In this respect

consideration has to be given to the type of the finished gear and the mode of manufacture. Certain defects may be present in steel for some particular types of gear which would be absolutely fatal to other types. Again, certain methods of manufacture may be impossible except with exceptionally good steel, while other methods may permit

of steel of a less perfect nature being used.

Methods of Fault Detection.—It naturally follows that the faults which the author is concerned with in this paper are those which the ordinary physical tests and chemical analyses do not reveal. While physical tests and chemical analyses are necessary, these by themselves tell one very little, and other tests have to be used before passing steels forward for gear manufacture.

One of the most useful tests the author has found is the hot acid etch, which has been described elsewhere previously. This method of testing was adopted three or four years ago on account of the many limitations found with other methods of steel examination. The hot-acid test will reveal faults, both important and unimportant, that are not revealed by any

other method of testing, and for that of greatest value. It is simple and quick to perform, and needs no expensive apparatus.

Most steel makers and users up till recently have relied on the sulphur print to give evidence of segregates and non-homogeneity in steel, but whilst this method is very useful and is the only one applicable in the case of large forgings or ingot sections, the author has proved that in many instances it entirely fails to disclose defects of a radical character which are absolutely fatal to high-grade engineering parts.

The defects revealed by the sulphur print are those of a grosser nature. The hot-acid test reveals everything that a sulphur print can detect, and a great deal more in addition. Briefly, the method consists of boiling a section of the bar, billet, or forging, in a mixture of hot hydrochloric and sulphuric acid of definite strength. The test is severe and

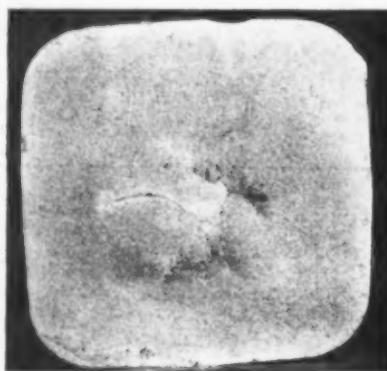


Fig. 1. Section from 4 1/2 in. square billet showing Residual Pipe after Hot Acid Etching.



Fig. 2. Section from partly forged billet showing Split Centre. This was Forged from billet shown in Fig. 1.

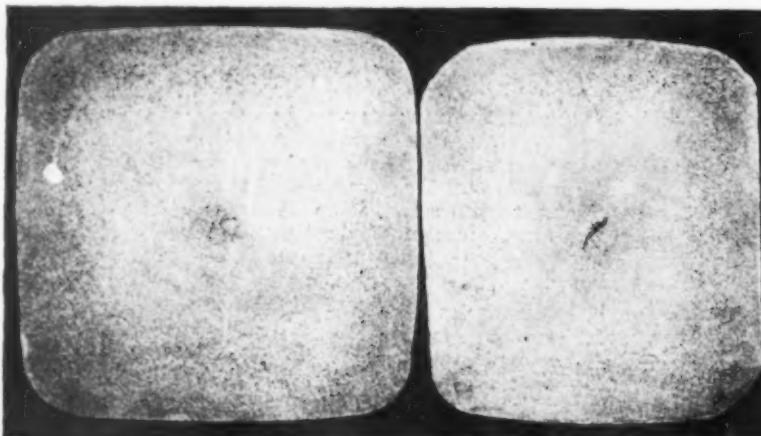


Fig. 3. Forged and unforger sections from billet showing Centre Weakness.

searching and exaggerates some types of defects, so that care has to be taken in interpreting the results. The sections are best prepared by cold sawing and surface grinding. Whilst a reasonably smooth surface is required, it is not necessary to have anything better than is used for sulphur printing, and even something less smooth than this will suffice.

The author has found the most useful all-round acid strength to be the following :—

Water	500 ccs.
Hydrochloric Acid S.O. 1·18	1400 ccs.
Sulphuric Acid S.O. 1·80	200 ccs.

On the other hand, steel which would, on sulphur printing, be passed as perfect will split on the slightest provocation under flat pallets, especially when working from square to round. It has been found that the hot-acid etch is the only sure guide as to what constitutes deleterious centre weakness.

A photograph of gross weakness, resulting probably from residual pipe, is shown in Fig. 1. Such material will split on the first blows of the hammer, as is shown in Fig. 2. To demonstrate how easily splitting occurs, Fig. 3 shows sections from the same billet—that on the right hand having had four blows only on the hammer.

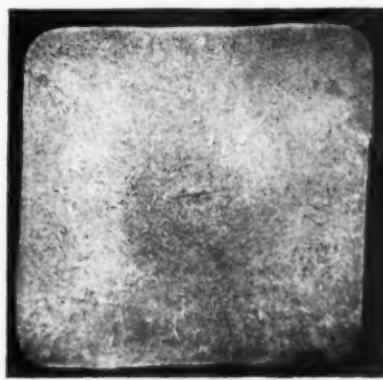


Fig. 4. Section from 3½% Nickel Chrome case-hardening steel billet split through too-rapid heating.

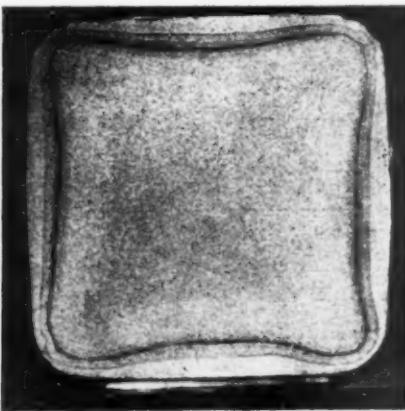
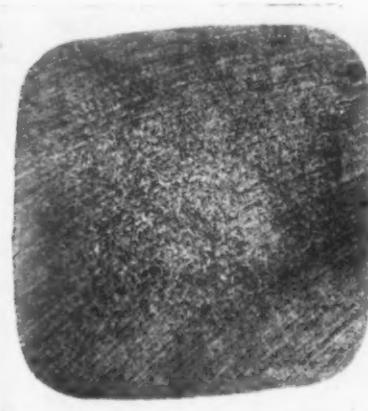


Fig. 5. Hot-etched section and Sulphur Print from same 5% Nickel case-hardening steel billet.



Where the work is wholly on steel of one particular grade, the proportions can with advantage be varied to suit that particular steel, but the above formula is most suited for general work. The time necessary to get a good etch is usually 20 mins. at 90–100°C., though longer than this is necessary for dense steels of 0·60% carbon and upwards. It is safest to continue the etching until all the grinding marks have disappeared, and every portion of the surface has been attacked fairly deeply.

Residual Pipe and "V" Segregates.—One of the most annoying faults and most prevalent in gear steels is centre weakness, due to residual pipe or "V" segregates. Most steel-makers insist strongly that any and every billet or forging must of necessity contain centre weakness. Whilst this is strictly true, nevertheless, in a well-manufactured steel the centre weakness is of negligible proportions, and experience has shown that in at least 80% of well-made steel this is the case.

Centre weakness reveals itself most markedly in the forging down of billets under flat pallets. Steel-makers are apt to condemn forging under flat pallets as a process which in itself causes split centres, but the author is convinced that this is not the case. The making of very many forgings is only commercially possible under flat pallets, and swages and dies are only practicable under certain limited applications. Experience has shown that a good steel free from centre weakness as revealed by the hot acid will forge under flat pallets without the slightest inclination to split centre with anything like normal care.

The common defence of steel-makers is that where a split forging occurs, if a section from the forging or a section from the billet shows an even sulphur print, the responsibility rests with the forge. This is definitely not the case.

Whilst the author would be the last to deny that bad forging practice can split even the best steel, it is much more difficult to do this than is generally imagined. Good steel will allow of an extraordinary amount of latitude in this respect.

As an example of a forging defect, Fig. 4 shows a split billet in high nickel chrome case-hardening steel, caused by too-rapid heating in the forging furnace. It will be noticed that the character of the crack is quite different from those shown in the previous illustrations.

Rim Segregation.—Another type of defect which is often unrevealed in a sulphur print in high-grade steels, is that of rim segregation. For many types of work this defect is regarded with complacency, and indeed aimed for in manufacture. For certain types of gears it may lead to enormous trouble, as is shown in the following case, which was traced back from 200 gears found defective at a late stage in manufacture. The hot-etched section of the original billet is shown in Fig. 5, alongside the sulphur print from the same section. It will be observed that the sulphur print is perfect. These billets were used to make upset stampings for automobile gearbox gears, and the sectioned and etched "teacake"—the next stage in manufacture—is shown in Fig. 6.

In the final stages of manufacture of these gears, very

faint thumbnail cracks were observed in the teeth, and a hot-etched section from one of the gears is shown in Fig. 7. It will be seen that the rim has developed into actual cracks during the last operation in the drop-stamp dies. Another and grosser type of rim segregation is shown in Fig. 8, and the resultant defective forging on the left hand in Fig. 9. An etched section of a sound forging is shown on the right hand in Fig. 9.

Ingot Corner Weakness.—Another type of defect which appears to be prevalent in high-grade steels is that of ingot corner weakness. As with other types of defects, this may vary from actual cracks visible to the naked eye in the bars or billets to potential cleavage planes only faintly discernible even after hot-acid etching.

An example of this defect in a 6-in. bar of 5% nickel case-hardening steel is shown in Fig. 10. It will be noticed how the original position and direction of the cracks persists right down to the final stage of rolling. Such ingot corner weaknesses, whilst seldom giving trouble during manufacture, unless of a particularly gross character, often cause service failures if at all marked. Their cause is somewhat obscure, but is connected with ingot mould design and casting temperature. They are very seldom revealed by sulphur prints, as they are usually unaccompanied by sulphur segregates.

Slag Inclusions.—The effect of slag inclusions in steel for gear manufacture is more serious than in probably any other instance. Steel for gears should be free from fibre, whether due to slag or segregated carbides. It is generally appreciated, of course, that fibrous material shows very high toughness when the stresses are at right-angles to the direction of the fibre. Such material is, however, very weak, when the stresses are parallel to the direction of the fibres. Unfortunately, it is impossible in gear

able to this cause, particularly where the pitch of the gears is fine. Slag inclusions, even of small dimensions, are, of course, inevitable in even the best steel, and if these are rolled out into thin plates and lie underneath the teeth in the area of maximum bending moment failure is bound to occur.

Variation in Analyses.—Another feature of gear steel which frequently causes trouble to gear manufacturers is variation in analysis over different casts. Whilst it is realised that it is impossible to duplicate analyses exactly over various casts, in many cases much more might be done in this direction.

The usual specifications for steels as regards analysis should be looked on purely as guides, as two steels, both conforming with the specification as regards chemical analysis, may vary very widely in physical properties, and thus cause trouble to the gear manufacturer. Another feature of certain gear steels is that whilst the composition meets the specification and the required physical properties on the usual 1½-in. diameter bars, the material will not give the required hardness on heavier sections than this. The 100-ton oil- and air-hardening nickel chrome steels of certain casts are notably often deficient in this respect.

Steel manufacturers should not be content with satisfying themselves that their steels meet the strict letter of the specifications only, but are also capable of giving satisfactory results over every size and section for which they are likely to be employed. One frequently finds, say, in air-hardening nickel-chrome steels, that where the section of the gear is over 1½ in., oil-hardening is necessary to secure the requisite hardness, thus, of course, increasing the distortion over what would be the case with air-hardening and increasing the risk of cracking.

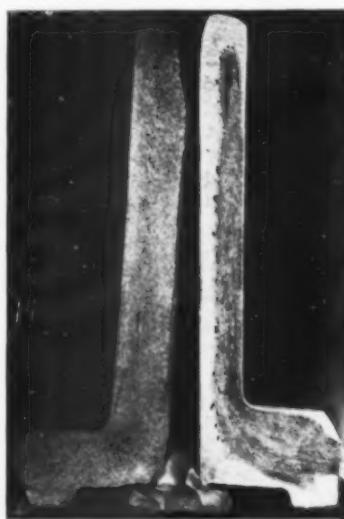


Fig. 9. Section of Defective Forging from billet shown in Fig. 8. Section of Sound Forging also shown for comparison.

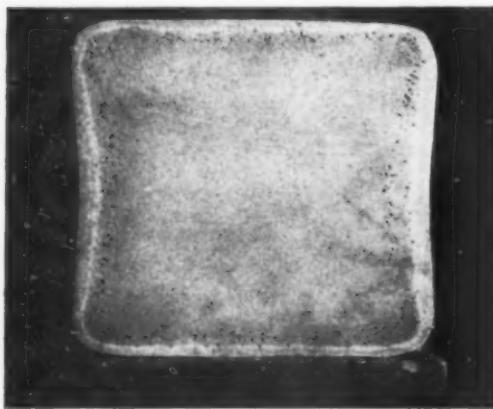


Fig. 8. Section from billet of Rimmed and Blown Steel.

manufacture to ensure that the stresses shall be at right-angles to the flow of the grain or fibre, and for that reason steel for gears should show physical properties as nearly uniform as possible, whether the test-pieces are taken with or against the grain—that is, the fibre or grain should be as little marked as possible.

Unfortunately, if one is to judge by publicity matter, time does not seem to be appreciated by steel-makers. Photographs of fractures illustrating the qualities of their steels, particularly those of the case-hardening variety, are invariably of the stringy rhubarb variety, indicative of pronounced fibre. Many failures of gears in service are trace-



Fig. 7. Etched section of Gear forged from Figs. 5 and 6 showing Rim Segregation developed into Cracks.

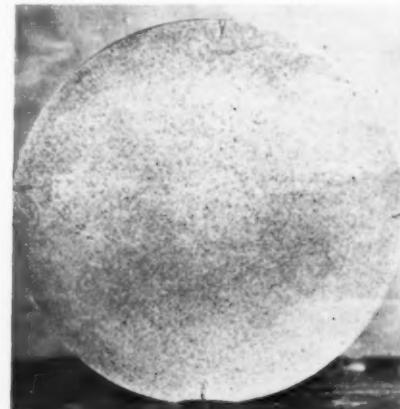


Fig. 10. Ingot Corner Weakness in 6 in. dia. bar of 5% Nickel Case-hardening Steel.

Another annoying trouble due to variation in analysis is widely differing core strengths in alloy case-hardening steels with material to the same specification. For instance, with two lots of 5% nickel case-hardening steel meeting the same specification, the core strength under the same heat-treatment may vary from 55 to 85 tons per square inch. Similarly, with 3½% nickel steel, the core strength may vary from 36 to 65 tons per square inch. Small variations in analysis make a large difference to these steels, and makers whose analyses are less apt to wander suit the gear manufacturer better than those whose steels, whilst conforming to the specifications, vary from cast to cast.

Welded Steel Structures

By Edward Dacre Lacy.

The Substitution of Welding for Riveting is receiving widespread consideration.

IT is now generally accepted by modern architects that most industrial and commercial buildings will in future have a framework of steel. In America, great strides have been made in the construction of steel-framed buildings. Structural steel is stronger and more permanent. One of the disadvantages of utilising steel for constructional purposes was the fact that until very recently both engineers and builders depended upon a system of riveted joints, which accounted for the terrific noise which was to be heard when a large building was being constructed by this means.

It is now apparent that in connection with structural steelwork the substitution of welding for riveting is receiving widespread consideration, but before welding takes the

As regards the question of employing intermittent or continuous seams, although in many instances an intermittent weld would give the degree of strength required, it is advisable when possible to make the welding continuous. A continuous seam ensures that the joint is hermetically sealed, thereby obviating ravages which occur in steel structures when water and atmospheric moisture get between the surfaces of the lapped edges and cause corrosion, this being a feature which cannot be prevented by periodical scraping and painting. Similar disadvantages occur where spot welding is employed, although spot welding has advantages in the shop where plates can be brought to the machine. Appreciable difficulty is experienced, however, in employing such a system on structures which have to be assembled *in situ*.

It is claimed by opponents of welding that too much depends upon the human element, whereas with riveting good or bad work is obvious from casual inspection. Those who have had experience in riveting work are aware that here also the human element is more or less a deciding factor, since it is possible for a riveted joint to have less than its design efficiency if the rivet is not driven tight or is overheated, if the rivet holes are not true, and driftpins are resorted to instead of reaming, and if the rivets are not driven in line with the axis of the centre line through the head. It is to be regretted that little information is available regarding the design of welded joints, and that no definite formula has been defined to assist the draughtsman, as is the case in riveted construction. In the meantime, it has been necessary to utilise existing knowledge regarding the design of riveted joints when designing those for welded joints.

The chief difficulty of riveted joints is that sooner or later the rivets are bound to work loose. It is interesting to speculate upon the reason of this, and in order to discover this reason, experiments were made with a riveted joint reproduced in rubber, and the flexure in that material was studied. The reason for taking rubber as the material was to decrease the modulus of elasticity. The deformation was increased under stress to the point where it was no longer necessary to measure it with micrometers, and it could be seen with the naked eye. All the conditions remained the same for practical purposes, with the exception of deformation of the stress. Upon application of the stress to the riveted joint made of rubber, it was clearly shown what happens in a riveted steel joint.

In the first place, owing to the reduced section of material due to the punching of rivet holes, the deformation through the reduced section was greater than the deformation through the original section, and it may be safely assumed that the deformation is inversely proportional to the section. This deformation occurred in three dimensions: the length, width, and thickness of the sections which had been pierced by the riveted holes were all changed. The rivet experienced some deformation and wear on its surface, due to the movement of the pieces joined, which shows that under stress the rivet did not fill the rivet hole, regardless of how completely the rivet filled the rivet hole under no-load conditions.

As the rivet did not fill the rivet hole under load conditions, it is reasonably certain that water or atmospheric moisture will get between the rivet and the rivet hole, and that eventually loosening of the rivet will occur in the same way as freezing water causes failures in a concrete street.



Lowicz Bridge, near Lodz, Poland, the first All-welded Public Works Structure.

place of riveting altogether, it will be necessary for architects to design buildings to be specially built by any of the welding processes in place of merely welding a design which was intended for a riveted structure.

There are several varieties of welded joints that should be studied by both engineers and builders who contemplate erecting welded structures. Of these, that of the butt-type provides the highest efficiency, providing the butted edges of the plates to be welded are properly prepared to allow for the full thickness of the plate being welded. Such joints welded by an efficient operator, employing the best type of electrodes, should give an efficiency of from 95 to 100%. Therefore, it is recommended that whenever the highest possible efficiency is required the butt joint should be specified.

Lap joints are usually employed in structural steelwork, but when tested under tension or under stress during working conditions, a lap joint is subjected to a certain amount of bending, since the joint tends to make up a straight line. This only applies, of course, to plates where the edges have not been jogged, and this stress must have some action on the weld metal which is not experienced in a butt joint. Lap joints can, however, be relied upon to give an efficiency of from 70 to 85% of the breaking stress of the plain plate, the actual efficiency being dependent upon the throat thickness of the metal comprising the fillet weld. The advantage of the lap joint is that it is easy to assemble, and does not require any preparation, as is the case with butt joints, though the advantage is somewhat reduced by the fact that the necessary steel tonnage is increased, due to the material required for the purposes of lapping the edges.

The chief reasons for riveted joints not being perfect are due to rivets not driven in tight, to being over-heated, holes not properly reamed, and the rivets not driven in line with the axis of the centre lines through the head. It is a well-known fact among rivet experts that it is impossible to ascertain the strength of a rivet joint unless the joint has been seen beforehand, and the job inspected after it has been done.

It is not always realised that the punching of holes necessitated for riveting causes more waste of material than that represented merely by the metal actually removed. The loss is equivalent to a strip the full length and thickness of the member in which the hole is punched, and as wide as the diameter of the rivet. This fact alone, by substituting welding for riveting, effects in the average case an appreciable saving, one of at least 15% of the steel tonnage.

The fact that electric arc welding in connection with structural steel work has not made greater progress can be attributed to a considerable extent to the restrictions imposed by authorities, and to the lack of interest on the part of constructional engineers as a whole. The recent publicity given to all-welded buildings already erected, and the economy effected by employing electric arc welding in preference to riveting has been the means of stimulating more widespread interest in the subject. The progress in America, for example, can be traced to the co-operation existing in that country between recognised welding engineers and architects working in conjunction through their respective societies.

Although England can justly claim priority in the welding of steel structural members, further progress has been retarded owing to the restrictions imposed on the use of welding by the London County Council (General Powers) Act, 1909. This act expressly prohibits welding in structures of more than one storey in height. In spite of these disabilities, in rural parts of England several light-steel structural buildings have been erected, and in one case the saving in weight approximated 35% on the standard riveted practice.

It is hoped that within a few years it may be possible to construct buildings in England of more than one storey by means of welding, owing to the fact that a Committee has recently come into being called "Steel Structures Research Committee," whose duty it is to investigate the welding of structural steel with a view to submitting in due course recommendations governing such work.

The position in Germany is somewhat similar to that in England, as laws have been passed prohibiting the use of electric welding in the building industry, but these laws seem to be more elastic in that country than in England, and as a result, the Chamber of German Engineers have drafted regulations which have already been passed by the Building Authorities, and have come into force, allowing structural steel work in Germany to be welded.

The City of Leipzig has gone its own way about the matter, and the following extract from the *Leipziger Neueste Nachrichten* will be of interest to all those connected with the construction of steel buildings: "During the last two Leipzig Fairs there have been exhibited in the building of the Steel Manufacturers test-pieces of butt-welded I-girders. Instead of the usual way of connection (strong plates with rivets or screws), the welding process has been preferred. With reference to the joining of steel by welding, this was not anything new, as pipes, boilers, vehicles, and ships have been welded for a long time. The development of electric arc welding, however, enables joining up large steel structures, such as buildings, roofs, halls, and bridges, cranes and buckets on a large scale, after tests carried out at some important firms and at the railway shops have shown that a welded joint is as safe as a riveted one.

"A law which allows the use of welding in steel structures

has been put before the Town Councillors of Leipzig for their sanction. The rules have been made out in agreement with the Police Department concerned. It is an improvement of the law, 'Town law for facilitating the construction of dwelling-houses of steel,' and will favour economically the house construction in steel. Besides savings in weight, there will be obtained savings in labour by the use of the filling materials (hollow bricks, plates, etc.), doubtless preference will be given to electric welding against riveting in steel structures in future."

On the Continent, especially in Belgium and France, welding has been utilised for structural purposes for a number of years, and there are no laws which hinder the progress of this industry. In America, in spite of the fact that a welded structure is now no uncommon sight, a number of regulations have been passed which naturally tend to safeguard those engineers and builders who are disposed to use a process which is still in its comparative infancy.

The Pacific Coast Building Office Conference has in this



Details of Louiz Bridge, showing Method of Construction.

connection formulated a uniform building code, legalising the construction of welded building, which has now been adopted by over forty cities and towns. The Pennsylvania Legislature now permits cities to adopt rules and regulations regarding welding, and the American Welding Society has formulated a code relative to steel building frames.

It is hoped by the British welding industry that the Institution of Welding Engineers, the Institution of Structural Engineers, and other similar bodies will soon get down to a definite policy regarding the question of welded structures, otherwise the welding industry of England will be left behind.

(To be continued.)

INSTITUTION OF AUTOMOBILE ENGINEERS.

The Presidential Address by Sir Herbert Austin, K.B.E., entitled "The Future Trend of Automobile Design," which he delivered on October 7, will be delivered at the following provincial centres:—

Oct. 28. The King's Head, Coventry, at 7.30 p.m.

Oct. 30. The Engineers' Club, Manchester, at 7.00 p.m.

Nov. 3. The Institution of Engineers and Shipbuilders, Glasgow, at 7.30 p.m.

SOCIETY OF ENGINEERS.

Oct. 21. A dinner to Miss Amy Johnson, C.B.E., B.A., Hon.F.S.E., at the Holborn Restaurant, at which she will give a talk on "The Attention that I gave to Jason's Engine during My Flight."

INSTITUTE OF MARINE ENGINEERS.

Nov. 11. "Tubes for High-Pressure Water-Tube Boilers," by Eng. Lt.-Com. S. F. Dorey, S.R., R.N., M.Sc.

METALLURGIA

The British Journal of Metals.

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CONTENTS

METALLURGIA

THE BRITISH JOURNAL OF METALS.

THE BASIC INDUSTRIES.

THE wave of optimism noticeable in some districts recently, which was probably fostered from the hope of an early revival, has not yet had its effect on industry. The conditions at home and abroad have not changed appreciably for the better, and the worldwide industrial depression continues. Although the depression is general, it must be realised that the proportion of trade being done in Britain is lower than was formerly customary, and it is of value to consider some of the factors that are influencing trade conditions with a view to inquiring into the prospects of a revival. This country is largely dependent on the basic industries, and its trade barometer is controlled by the condition in the coal, iron and steel, and the textile trades. In regard to the latter, the optimism prevailing is based on reasonable assumption, as many mills have reopened as a result of new orders. The coal trade, however, has suffered many adversities. It must be remembered that other forms of power are being increasingly used: electricity is being developed to a remarkable extent, water power is being harnessed, and oil fuel, particularly in the mercantile service, is making rapid progress to the exclusion of coal. In addition, industries have been concentrating with the object of effecting economies, and a reduction in coal consumption has resulted. These changes and economies have naturally affected the export trade, and have created difficulties that are not likely to diminish. It is unfortunate that investigations on the effective and economical use of coal were not undertaken earlier, as the problems arising out of these difficulties were foreseen long ago. The progress in the development of low-temperature carbonisation and distillation processes is not yet sufficient to be regarded as an economic means of producing oil and spirit; much research work is likely to be involved before the problem is solved.

The reduction in the export of coal has had a marked effect on shipbuilding, although the sale of redundant vessels to foreign owners has, in a measure, influenced new building. The importance of this is appreciated sufficiently to warrant an inquiry into the possibility of buying old vessels to be dismantled and sold as scrap.

The comparatively low demand for new ships is reacting on the steel industry, but this is not the primary cause. It is the phenomenally low prices prevailing on the Continent that have had the most serious effect on the British products. It was confidently asserted that pre-war prices would never again operate, but Continental steel billets and sheet bars have been sold recently at prices almost similar to those prevailing immediately preceding the war. It must not be assumed that this is an indication of inferior plant or facilities on the part of British producers. On this point it is worthy of note that Mr. Sillars, manager of the South Bank plant of Messrs. Dorman, Long and Co., Ltd., who recently returned from an extensive tour of continental works, is very emphatic that British plant and facilities are better than those abroad, and the foreign producer has no advantage in this respect. This bears out the views of a sub-committee of the Civil Research Committee after visiting the chief works in five continental countries some time ago. In spite of this, the difference

in price between British and Continental steel is alarming, and can only be due to transport charges, wages, and taxes being on a higher scale than is operative on the Continent, because it is not likely that continental producers will sell at considerable loss rather than hold stocks.

The depression in the steel industry on the Continent is evidently just as acute as here, because the Cartel, which is still in operation, has reached an agreement to curtail steel production a further 15% during the last quarter; this is in addition to the 10% reduction imposed during the third quarter. The effect of this decision will undoubtedly tend to steady the market. It is interesting to note that the Cartel has re-established the original scale of fines for over-production.

The process of reorganisation that has been developing in the iron and steel industry, and indeed in other industries also, is the result of economic necessity. It is being pursued with the sole object of facilitating and cheapening production to ensure more favourable conditions in competing in the world's markets. The process is involving both the structure of industry and the method of production. The efforts made in centralising production and modernising plant and equipment have materially reduced the amount of labour required to produce a given unit, and at a time when demand for production does not absorb the labour available. Thus, reorganisation, which is claimed as a popular remedy for unemployment, is one of the causes of the evil it is trying to remedy. In effect, the readjustments made have aggravated the unemployment problem, much of which is not due to depression in trade, but to structural alterations. Actually, the process has reduced the cost of production, but has involved a social loss, and in view of this fact it is rather remarkable that wages have not been influenced to any appreciable extent.

Unemployment will undoubtedly continue until the lower cost of production has helped the basic industries to regain and expand their markets, but it is necessary to appreciate that the unemployment resulting from the reorganisation of industry is a lesser evil than unemployment arising from relative inefficiency.

The basic industries have felt the effects of adverse conditions to a greater extent than other industries, and it speaks well for the equipment and management that they have stood up so well against violent market fluctuations. British producers are now in a better position to compete in the world's markets, but it will be necessary for them to accommodate themselves to a lower level of prices, at least until the demand is less easily satisfied than at the time of writing. With continued effort, economy, and sacrifice fairly distributed among all concerned, together with that determination that characterises the British industrialist, the future can be faced with assurance; but the effort would be facilitated, and the position considerably improved if the Government would assist by mitigating the unequal burdens industry is called upon to bear. The status of Britain as a manufacturing and distributing centre is unimpaired, and because of its established relationship and connections in the world's markets, an increased export trade would effectively restore prosperity and materially brighten the prospects of the basic industries.

THE AIRSHIP R 101.

THE country was appalled by the suddenness and the magnitude of the disaster which befell the R 101. Not only has the catastrophe stirred the people of this country, but it has affected the peoples of the whole world. It has been a disaster to aviation generally, and will, in a measure, tend to retard progress. So many people immediately jump to the conclusion that airships are unsuitable to overcome the difficulties to which they are subjected, but the same has been said of all pioneering efforts to overcome the forces of nature. This calamity has been a bitter disappointment to British aviators: in the history of aviation in this country only one disaster compares with it, that of the R 38, which fell in the Humber, and which lost forty-four precious lives. It is this loss rather than the material loss, which is of vital importance in the cause of aviation. These men had concentrated, and become specialists on the work for which they gave their lives. Yet it would be misfortune, which the brave men who perished would be first to deprecate, if the tragic fate of R 101 were allowed to undo utterly the work which they had at heart.

To the British Empire the development of aeronautics is a task of instant importance: no nation will derive more from flying than we stand to gain. We possess immense overseas territories which afford an ideal field for the opening of aerial routes. Rapid communications are the very breath of life to the British Commonwealth of Nations, and while this calamity may cause a set-back, progress will continue. Probably the truest reverence to the victims of this disaster is not to abandon as hopeless the struggle in which they have fallen, but to find other and surer means of attaining the ends for which they died.

THE IMPERIAL CONFERENCE.

THE tasks before an Imperial Conference are always important, but on this occasion the results from the deliberations of the representarives now assembled are awaited with not a little anxiety, because of a very important economic issue. The Prime Minister has broadly defined the scope of the work to include inter-Imperial relations, foreign policy and defence, and economic questions, and it is the readjustment of economic relations, envisaged by the last section, that is arousing more than ordinary interest. Many subjects will necessarily be discussed to reach common interest, with a view to exploring all avenues that are likely to promote mutual well-being. The main question is whether the commercial relations within the Commonwealth can be advanced to foster and maintain mutual prosperity within the Empire, and, if there are possibilities, what is the best way to achieve this end.

Rapid means of transport is fast reducing the distances between the Dominions and the Mother Country, and increasing the possibility of the formation of a Commonwealth of Nations. The Mother Country naturally desires to increase her markets for manufactured articles and coal, and the consuming possibilities of the Commonwealth have not yet been adequately explored, to determine the extent to which co-operative bargaining can be fostered.

Obviously, any Conference on this subject would be futile if the Mother Country alone benefited, but the Dominions have immense stores of agricultural produce and raw materials which they desire to market. It is this mutual exchange that is desirable, and which involves many complex and difficult problems, the solution of which will be a heavy tax on the Empire statesmen. The Government have stated that they are not wedded to any particular idea, but that they are ready to examine all proposals with an open mind. They are strengthened in their attitude by the Trades Union Congress. Whatever may be the final results of the deliberations, it is hoped that not only will new avenues be opened for advancing mutual prosperity within the Empire, but that the cordial good feeling already existing between the various countries will be further cemented.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Oct. 16. Charter Dinner.
Oct. 17. General Meeting. Presidential Address by Loughman St. L. Pendred.
Nov. 7. Thomas Hawksley Lecture, "The Machinery of the Earth," by Professor J. W. Gregory, LL.D., D.Sc., F.R.S.

INSTITUTE OF METALS.

Oct. 28. Swansea Section. "Impurities in Copper," by W. Rosenhain, D.Sc., F.R.S. Members are asked to make this correction in their programme.
Nov. 4. North-East Coast Section. "Gases in Metals," by S. L. Archbutt, F.I.C.
Nov. 10. Scottish Section. "The Application of High Nickel, Nickel-Copper Alloys, and Pure Nickel in Industry," by N. C. Marples, M.Sc.
Nov. 11. Swansea Section. "Alloys—Some Reasons for their Composition," by H. W. Browndson, M.Sc., Ph.D.
Nov. 13. Birmingham Section. Discussion on "Metals and Alloys of the Future," to be opened by W. H. Hatfield, D.Met.

Nov. 14. Sheffield Section. "Unsoundness in Metals," by H. Hyman, Ph.D.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Oct. 16. Opening meeting of Tees-side Branch to be held at Middlesbrough. Mr. J. R. Dippie will succeed Mr. W. G. Richards as Chairman.
Oct. 24. General Meeting of the Institution. Mr. John McGovern will be installed as President by Mr. Launcelet E. Smith, the retiring President.

THE INSTITUTE OF BRITISH FOUNDRYMEN. BIRMINGHAM BRANCH.

Oct. 17. "Foundry Theory and Practice in America," by J. G. Pearce, M.Sc., M.I.E.E., Director, British Cast Iron Research Association.
Oct. 29. Visit to works of Universal Grinding Wheel Co., Ltd., Stafford.

EAST MIDLANDS BRANCH.

Oct. 25. "The Human Factor in the Jobbing Foundry," by A. S. Worcester, Huddersfield (at Leicester).
Nov. 15. "Foundry Sods of Nottinghamshire and District," by F. Hudson, Birmingham (at Nottingham).

LANCASHIRE BRANCH.

Nov. 1. "Fabricated Structures." Discussion.

LANCASHIRE BRANCH—BURNLEY SECTION.

Nov. 11. "Some of the aims and objects of the Institute of British Foundrymen," by R. W. Stubbs, President, Lancashire Branch.

LONDON BRANCH.

Oct. 16. "Cast Alloys for High Temperature Service," by Prof. D. Hanson, D.Sc., Birmingham.
Nov. 13. "Foundry Theory and Practice in the United States," by J. G. Pearce, M.Sc., M.I.E.E.

MIDDLESBROUGH BRANCH.

Nov. 14. "What happens to the Metal inside a Cupola," by F. Hudson.

NEWCASTLE AND DISTRICT BRANCH.

Oct. 25. "The Production of Large and Medium-sized High-Class Iron Castings," by W. Scott.

SCOTTISH BRANCH.

Nov. 8. "The Moulding and Casting of Bronze Plates," by Robert Liddle.

SHEFFIELD AND DISTRICT BRANCH.

Oct. 24. Smoking Concert and General Discussion opened by Branch President.

Nov. 6. Works Visit to Staveley Coal and Iron Co.'s Colliery, Staveley.

WALES AND MONMOUTH BRANCH.

Oct. 25. "Making Moulds without Patterns," by J. Bennett, Ebley, Gloucester (at Newport).

Nov. 8. "Nickel in Cast Iron," by W. T. Griffiths, M.Sc., F.I.C., F.Inst.P., London (at Cardiff).

WEST RIDING OF YORKSHIRE BRANCH.

Nov. 1. Visit to Works of J. Blakeborough and Sons, Ltd., Woodhouse Works, Brighouse.

THE INSTITUTION OF WELDING ENGINEERS.

Oct. 16. "The Replacement of Castings by Welding," by P. L. Roberts.

(*Further Meetings on page 202.*)

*The Problem of Machinability—Measurement

By Edward G. Herbert, B.Sc., M.I.Mech.E.

PART II.

Anomalies of Direct Measurement—Study of Cutting Action—Work-Hardening Capacity.

ENOUGH was said in Part I. to indicate the general character of the various methods which have been employed for the direct measurement of machinability, though nothing more than a general indication has been attempted. Of indirect measures derived from a knowledge of the physical properties of the metals, their hardness, tensile properties, and so forth, a very few words will suffice. No investigator of machinability has been successful in finding a quantitative relationship between the machinability of metals, as indicated by any method of measurement, and any known physical property of the metals themselves. The position has been summed up by Boston, who says (Conclusion 5): "While the Brinell number is seen to vary almost directly with the Rockwell number and the ultimate strengths of steels in tension, shear, and compression, its relation to the cutting force, energy, torque, thrust, or penetration of steel or non-ferrous metals, seems remote, and in many instances, entirely misleading."

as measured by planer force, and that no other measure places them in that order. Similar anomalies have been found by Krekeler, who showed that while four steels were placed in a given order as regards machinability in turning, the order was reversed when machinability was measured by drilling.

Even more marked were the anomalies shown by the writer's measurements of machinability by turning and sawing. It was found, for instance, that a chrome vanadium steel was much easier to saw when in its normalized and harder state than when annealed and in its softest state, whereas, on the lathe, the softer steel was cut with ease, and the harder required a reduction of cutting speed before it could be cut at all. The following are the actual figures:

Chrome Vanadium Steel.	Pendulum Time Hardness.	Sawing Strokes per Cut.	Turning Speed Ft. per Min.
Annealed	13.4	278	61
Normalised	20.8	143	45.5

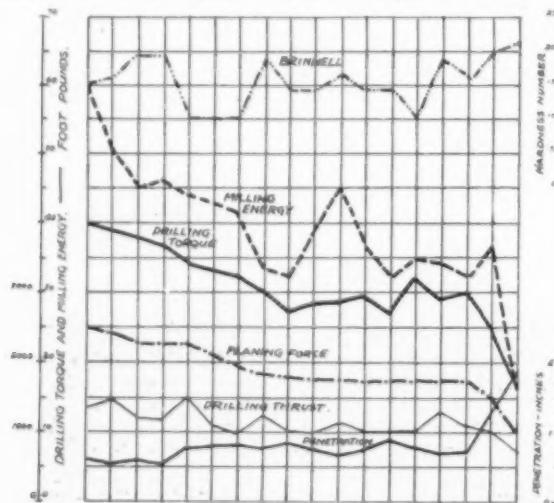


Fig. 4.—Result of Investigations on Eighteen Steels.

When we turn to the results of the various direct measurements of machinability, we find, on comparing them, that their lack of correspondence with the physical properties of the metals in question is matched by an equal or greater lack of correspondence between themselves. It is not too much to say that no two measures of machinability show a proportionate or consistent correspondence in the results obtained from a given group of metals, and that no two methods of measurement place the metals in the same order as regards machinability, or in the same order as their hardness or tensile characteristics. This is illustrated by Fig. 4, which shows, in the case of eighteen steels investigated by Boston, the Brinell hardness, the energy measured by the milling dynamometer, Fig. 3, the torque, thrust, and penetration of a twist-drill, and the force exerted by a planer tool. It will be observed that the steels are arranged in order of their machinability

So far, then, a study of machinability of metals by all the methods available appears to lead merely to a whole series of anomalies and inconsistencies. It has been found possible, by carefully conducted tests on the lathe, to find the speeds at which a number of typical steels could be cut under conditions arbitrarily chosen, but there is no assurance that these tabulated results would even approximately represent the machinability of these steels under different cutting conditions on the lathe, while their machinability in drilling, milling, planing, sawing, or any other process, would probably be found to be not only entirely different, but in a different order in each and every case.

The Study of Cutting Action.

It was with the hope of finding the underlying principles which influence the resistance of metals to cutting tools that the writer undertook a detailed study of cutting action. It seemed hopeless to expect to understand the anomalies referred to above without a more definite knowledge of what occurred when a chip was taken from a bar by a tool of given shape, and investigations, extending over some years, were therefore made into the mode of chip formation by three types of cutting tools: an obtuse-angled roughing lathe tool, an acute-angled knife tool, as used in bar lathe work, and a power hack-saw.

The method of study was the same in each case. The machine was suddenly stopped with the tool in the cut, the tool was withdrawn, leaving the chip attached to the bar, and a section was made through the chip and bar by careful grinding and polishing. The section was mounted in pitch, etched, tested for hardness at many points with the Herbert Pendulum Hardness Tester, and photographed under the microscope. A typical chip section is shown in Figs. 5 and 5a, reproduced from a paper by the writer ("Work-Hardening Properties of

*Continued from page 171 in September issue.

Metals," Amer. Soc. of Mech., Eng., 1926), and represents a chip made in stainless steel with a lathe roughing tool.

The most notable feature in this micrograph is the structure known as the "built-up edge." A careful study has been made of a large number of chip sections in which

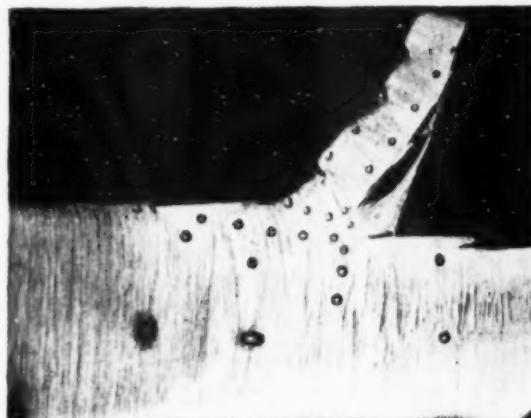


Fig. 5.—Chip of Stainless Steel ($\times 10$).

the built-up edge is present, and it has become clear that it is formed of successive thin layers of metal dragged off the under-side of the chip, and welded together into a compact mass. In rough turning, the built-up edge is often firmly attached to the point of the tool, and the same applies when cutting is done by obtuse-angled tools, such as the teeth of hacksaws and files. When the tool has an acute angle, as is customary in the knife tools used in the bar lathe, the built-up edge is not a permanent structure, but slips off the tool as soon as it is formed, the process taking place as often as 50 times a second, and the discarded edges forming a succession of ridges on the under-side of the chip; but in all cases where it is present, the built-up edge is the implement which actually does the cutting. The tool merely serves to support it. Most important of all, the cutting angle of the built-up edge is always more acute than the cutting angle of the tool, and it is obvious that, in so far as the resistance offered by the metal to the cutting tool is dependent on the cutting angle, it must be the angle of the built-up edge, and not the angle of the tool, which is significant.

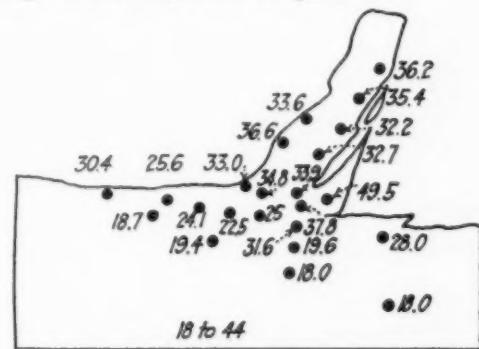


Fig. 5a.—Hardness Induced by Tool in Stainless Steel.

Here, then, we have a new and perhaps a variable factor in cutting which in itself is sufficient to account for almost all the anomalies that have been mentioned. If it were found, for instance, that in cutting a given metal under certain conditions a keen and efficient built-up edge was formed, while under other conditions the built-up edge was either inefficient in form or entirely absent, then it would inevitably happen that the metal would be easily machined under the former conditions, and difficult to machine under the latter, and this is exactly what has

been found. In Fig. 6 is shown the chip made by a hacksaw tooth in a steel which has been normalised (2 CL, in Fig. 1), and has a diamond time hardness 17.0. The saw-tooth had zero top rake, but the actual cutting was done by an efficient built-up edge with a "natural" top rake of 26° . Cutting was done freely, and with very little blunting of the blade. In Fig. 7 is a chip made by the same saw-blade in the same steel in its annealed and soft condition, the diamond time hardness being only 12.5 (1 CL, in Fig. 1). In this case the built-up edge was rudimentary and inefficient in form. There was great resistance, slow cutting, and

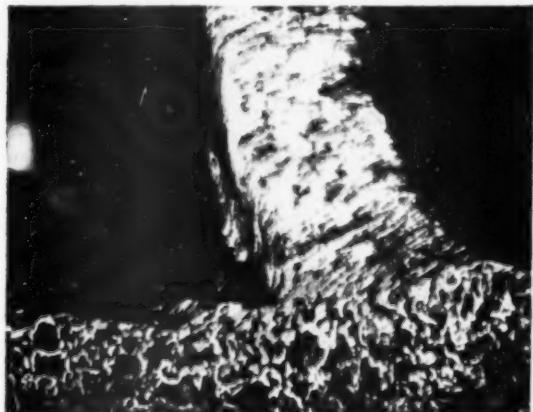


Fig. 6.—Built-up Edge in Hacksaw Chip ($\times 100$).

rapid blunting of the saw. And although the soft steel was difficult to machine with a hacksaw, it would not at all follow that it would be difficult to machine in the lathe. Experiments with this same annealed steel showed that when the cutting speed was below 18 feet per minute, no built-up edge was formed, while at all higher speeds, the tool was reinforced by a keen and efficient built-up edge.

In other cases it was found that whereas cutting with a sharp saw was relatively inefficient, the number of strokes per cut progressively decreased as the saw became blunt. It was found that under certain conditions a blunt tool was more favourable to the formation and retention of a built-up edge than a sharp one. The blunter tool was the

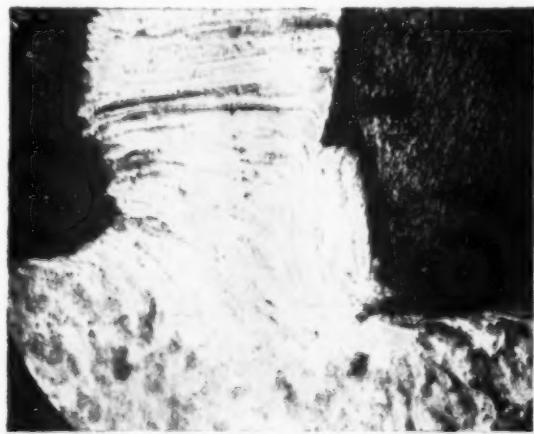


Fig. 7.—Built-up Edge in Hacksaw Chip ($\times 100$).

more efficient, or conversely, the steel was relatively easy to machine with the blunt tool, but difficult to machine with a sharp one.

Hardness Induced by Cutting Tools.

Another and a frequent cause of anomalies in the behaviour of metals in machining will be understood from

Figs. 5 and 5a. Hardness tests were made with the Pendulum Hardness Tester at many points in the section of the cut, not only on the chip itself, but on the metal below and in front of the tool. It was found that steel possessing the original hardness of the bar (in this case, 18.0 time hardness, equivalent to 116 Brinell) did not exist anywhere in the region of the cut. The steel had been work-hardened by deformation long before it became separated in the form of a chip. The tool was, in fact, cutting work-hardened metal, and the degree of hardness existing in the metal which was about to be cut, though always higher than the original hardness, was found to depend upon two independent factors: the capacity of the metal to be hardened by deformation, and the degree of deformation caused by the particular cutting conditions. The first factor, work-hardening capacity or "maximum induced hardness" is an inherent property of the metal which can easily be measured with the Pendulum; the second factor on the speed and on the cutting angle of the built-up edge formed on the tool. As an example, the stainless steel shown in Fig. 5, containing 0.11 Carbon, 15.7 Chromium, 10.5 Nickel, is very soft (116 Brinell), but has

a high maximum induced hardness equivalent to 440 Brinell as measured with the Pendulum. This steel, in spite of its softness, is very difficult to machine with a tool whose form is such as to cause considerable deformation, but relatively easy to machine with a very keen tool which removes the chip with minimum deformation.

A further example of the influence of these two factors, work-hardening capacity and degree of deformation, is that of cast iron. This metal has a relatively high indentation hardness and a very high work-hardening capacity, yet it was machined both in the saw and in the lathe more easily than any of the steels, including some whose original and induced hardness were much lower. The explanation of this anomaly was found by the method of chip analysis illustrated in Figs. 5 and 5a. Although the cast iron had a high capacity for work-hardening, it was not in fact work-hardened by the tool. Owing to its brittleness, the chips were separated without plastic deformation, and the chips were no harder than the bar from which they were separated. They were much less hard than the chips taken from soft steels, the latter having been highly work-hardened by deformation.

(To be continued.)

Practical Difficulties Associated with Electrodeposition of Chromium

By J. W. Cuthbertson, M.Sc.

ALTHOUGH the electrodeposition of chromium has passed far beyond the experimental stage, the process is still, in some respects, unsatisfactory, and is beset by several practical difficulties, said the author, in a paper which he read before the Electroplaters and Depositors' Technical Society, at Northampton Polytechnic Institute recently. On repetition work the difficulties are not so great as those encountered on general work. The conditions necessary for obtaining satisfactory bright chromium deposits are dependent upon many factors, and the author emphasised the importance of the careful preparation of the work, paying special attention to the production of a good, tight nickel deposit under the chromium.

In considering the vats suitable for the electrodeposition of nickel, he stated that most satisfactory results are obtained from a warm bath of simple composition, agitated and filtered. A deposit of 0.001 in. should be applied to all steel work, and the nickel vat should be capable of doing this in 30 mins. or less. In regard to vats for chromium plating, it is a great convenience to have vats according to size of work being done. Even if only one dynamo is available, capable of running each vat singly, the opinion is expressed that better results are obtained, if small articles are plated in a vat of small dimensions. Vats are frequently of insufficient depth. The difficulty in operation is objectionable, but if a platform is arranged around the vat at a height of 12 in. to 18 in., no inconvenience should arise.

Plating Solutions.

As a result of many experiments with different solutions, the author concludes that the best deposits are obtained from a solution of chromic acid and chromium sulphate in water. The tank is usually made of iron, the sides being glass lined, heated by gas burners from below. Iron is not an ideal material to use, but is as good as anything obtainable at a reasonable price. The anodes should be of lead. From time to time, attempts have been made to introduce iron anodes, but they are quite unsuited to the purpose. Unless electrolytic iron is used, it will dissolve in the solution, the rate at which this occurs depending on the carbon content. High carbon steel anodes are rapidly attacked. The greatest disadvantage in the use of iron or

steel anodes is to be found in the effect upon the working of the bath. Iron tends to increase the concentration of trivalent chromium in the solution: this leads to a decrease in the throwing power, and reduces the working range in which the vat will produce good, bright plate. Iron also increases the resistance of the solution. If lead anodes are used, a much lower value of trivalent chromium content results, due to the higher oxygen overvoltage of these anodes. Intermittent plating, which with iron anodes tends to raise the trivalent chromium in solution, has very little effect in this direction when using lead anodes. A certain amount of iron does dissolve from the tank, as is shown by the "ageing" of a new solution, but the quantity is usually so small that it has no serious effect. Provided the iron content is kept low, the solution will give satisfaction. If, however, the iron increases appreciably, say, to several grams per litre, the vat may be profoundly affected. It has been stated by Pinner and Baker* that increasing the iron content to 6 grms. per litre will greatly contract the sulphate ratio range—that is, the ratio between CrO_3 and SO_4 must be kept within narrow limits if the bath is to produce bright plate. In the author's opinion, considerably less iron than this can have a very detrimental effect. Iron may increase in the vat through careless plating of steel articles, particularly if these are left for any length of time in the vat without any current passing through them.

The sulphate ratio of the vat is important. Generally speaking, we may say that there are four variable factors in chromium plating—viz., temperature, current density, chromic acid concentration, and sulphate concentration. All these are intimately connected; thus, if we have a bath of certain composition working at, say, 40° C., we may find that, with a current density of 75 amps. per sq. ft. a good deposit is obtained. If, however, we vary the chromium sulphate content without making any change in any of the other variables, we may obtain dull plate, or possibly nothing but hydrogen. In bright chrome plating baths the ratio between chromic acid and chromium sulphate may be expressed in the form—

$$\frac{\text{CrO}_3 \text{ molarity}}{\text{SO}_4 \text{ normality}} = \text{a factor, approximately 50.}$$

The exact value of this depends upon the composition of the remainder of the bath, and is generally higher, due to the presence of both trivalent chromium and iron.

When the right conditions are obtained, the chromic acid and the sulphate content of the vat should be determined, and an attempt made to keep to this composition continuously. The chromic acid is easily determined either by titration or by means of a hydrometer. The chromium sulphate estimation is not, unfortunately, so simple. If barium chloride is added to the plating solution, the barium sulphate thrown down is contaminated with barium chromate. It is, therefore, necessary to reduce the solution so that the chromic acid is converted into a chromic salt. There are several ways in which this can be done, hydroxylamine hydrochloride being very suitable for the purpose, although somewhat costly. Full details of the estimation of sulphate, both gravimetrically and by a method based upon the turbidity of the solution caused by the barium-sulphate, are given in a paper by Willard and Schneidewind.[†]

Additions to the Bath.—Whenever chromic acid is added to the vat, and this should be done daily if much work is passing through, it is essential to use only the pure material, free from sulphates. This is usually the only addition required, but some platers add chromium carbonate and chromium hydroxide to the solution. Such a practice is to

be deprecated, as it can do nothing but harm as it increases the trivalent chromium concentration.

A properly developed technique, together with careful individual attention to the details of the process, assist materially in the production of a sound finish. It is frequently stated that the article on which the deposit is being made must gas freely in the vat. This is generally the case, but the gassing also causes considerable trouble, particularly in the case of articles which are perforated or have sharp angles and corners. Such articles require special preparation, all holes and apertures being stopped with corks. This is a tedious and troublesome process, necessitating a large stock of corks to meet all requirements. By exercising forethought and some ingenuity in the method of plating such articles, the need for corking can be minimised, although in some cases it will still be essential. Anode arrangement is also important in view of the poor throwing power of warm chromium plating baths.

The hangers used for conveying the current to the articles are made of copper rod, and a sufficient number should be used to carry the current required without overheating. The author referred to many examples of plated work and commented upon difficulties encountered.

* W. L. Pinner and G. M. Baker, *Trans. Amer. Electrochem. Soc.*, Vol. IV, 1929.
† H. H. Willard and Carl Schneidewind, *Trans. Amer. Electrochem. Soc.*, Vol. Ixvi, 1929.

Electro-Chemists' Convention

Electro-chemists and Engineers from all parts of the World attended the Semi-Annual Convention recently held at Detroit, Michigan.

CORROSION being one of the chief engineering topics of the present day, it was natural that considerable interest should be displayed in the discussion on the prevention of corrosion of metals in the automobile industry, which was in charge of Dr. F. N. Speller. The results of an elaborate investigation was presented by Messrs. C. L. Hippenstein and C. W. Borgmann on the protection of iron and steel against corrosion by the application of zinc and cadmium coatings. Controlled tests were carried out in order to judge the relative protective life of the two coatings. The results from these tests indicate that zinc and cadmium receive their wide use as protective coatings because of their electrochemical relationship to iron and steel. Zinc definitely acts as a protection to iron in any electrolyte of sufficient conductivity to yield a certain minimum current density in the resulting cell.

The relation of cadmium to iron has been the subject of considerable discussion. U. R. Evans, H. S. Rawdon, and others have shown that cadmium protects iron from corrosion. Others, including G. N. Lewis and M. Randall, and H. J. Creighton and C. G. Fink, have reported that the standard potential of cadmium is electropositive to that of iron, while the standard potential of zinc is definitely more electronegative than that of iron. However, it is safe to assume, from corrosion data, that the electrode potential of cadmium is close to that of iron, and may be on one side or the other, depending upon the type of environment to which it is subjected.

In very dilute electrolytes, such as are encountered under atmospheric conditions, the actual protection of iron and steel by either zinc or cadmium coatings is confined to minute areas, the important factor is that they do not accelerate the corrosion of iron or steel at discontinuities in the coating, as do coatings of copper, nickel, and chromium. These considerations show that the life of a zinc or cadmium coating is determined primarily by the rate at which a given atmosphere will corrode the coating itself.

Many claims have been made in late years of the advantage of cadmium coatings in comparison with those of zinc, from an atmospheric corrosion standpoint. Other persons, who are not quite so optimistic, hold that equal weights of

coating of the two would be equally resistant to atmospheric attack. It has been shown that in an industrial atmosphere a relatively heavy coating of zinc, or zinc alloyed with mercury or cadmium, will corrode much less rapidly than an equal weight of coating of relatively pure cadmium. These results become of more consequence, too, when it is considered that even in strictly residential districts the industrial gas content of the atmosphere, especially in the winter, is quite high, owing to the burning of soft coal, oil and gas for fuel.

An unusual illustration of the corrosion of aluminium by an alkali was disclosed by Oliver W. Storey. It is well known that the extensive use of sheet aluminium for oven walls, and especially the walls of electrically-heated ovens for domestic purposes, is based on the non-rusting and practically non-corroding properties of this metal under these conditions. It, therefore, was rather surprising and disconcerting to a manufacturer of such electrically-heated aluminium ovens to have one returned, after being used for domestic purposes for several years, because the aluminium oven walls had pitted through.

An inspection of this pitted sheet aluminium, 1 mm. (0.040 in.) thick, indicated that the corrosion occurred on the side away from the oven interior—that is, adjacent to the insulating material. The corrosion, therefore, did not become apparent until the aluminium was punctured. On investigation, the corrosion was found to be caused by the caustic soda of the sodium silicate adhesive used for the built-up asbestos insulation, in the presence of excessive moisture. The sheet asbestos acts as a dialyzing membrane for the sodium silicate, and allows silicate-free caustic soda to reach the aluminium sheet.

The plating of radiator shells was discussed by Prof. O. P. Watts, and photographs of the plating on radiator shells were shown, accompanied by a description of the preparation of the steel and the details of plating. Heavy electro deposits on steel were prescribed, to insure lasting protection against corrosion. The proper preparation of the steel surface preliminary to plating was stated to be an important factor. The actual thickness of various copper,

nickel, and chromium deposits was determined microscopically. Tests were made for pin-holes and cracks in the plates. Finally samples were immersed in a 35 g./L. NaCl solution, and many specimens were shown to be in good condition after 23 days' immersion.

The improvement in the resistance to corrosion of chromium-plated automobile parts by heat-treatment was discussed by R. J. Wirshing, who stated that copper panels, chromium plated at low current densities and high bath temperatures, were more resistant to calcium chloride corrosion than panels plated at higher current densities or lower temperatures. Greater corrosion resistance is attributed to lower hydrogen content of the plate. Upon removing most of the hydrogen through heat, a seven-fold improvement in corrosion resistance was noted.

Methods of procedure, analysis, and calculation were discussed by Karl Pitschner, which provide a definite means of evaluating the data of corrosion tests on the ferrous metals, of determining the actual protective value of coatings on these materials, and of comparing their tendencies to pit under corrosive conditions. The procedure adopted depends on a method for determining the element iron in the metallic portion of corroded samples by means of a separation of corrosion products from metallics, with crystalline iodine.

During recent years the use of calcium chloride for laying dust on roads has become fairly common, and H. C. Mougey infers that this has brought about more extensive corrosion. He stated that calcium chloride is much more corrosive to plated parts than sodium chloride. However, no quantitative relation between the salt-spray test and the calcium chloride spray test could be established. Calcium chloride will attack chrome-plate more easily than sodium chloride, due possibly to the interaction of the carbonic acid of the air with the calcium chloride, forming free hydrochloric acid. The calcium chloride spray test is recommended to the chromium-plating industry as an aid in developing a more resistant chrome plate.

At the second technical session Prof. Dwight K. Alpern demonstrated a new photo-voltaic cell applicable to talking moving pictures and many other contributions were concerned largely with the electro-deposition of various metals and alloys, and the electro-chemical behaviour of batteries and cells, including a review of the whole theory of electrode behaviour, by Prof. E. Newbery which included single potential determinations, overvoltage, transfer resistance, valve action and passivity. Normal electrode potentials, he stated, are periodic functions of the atomic numbers of the elements, and those of the inert gases are probably zero.

When a gas is liberated at an electrode, transfer resistance always appears, and is due to the purely ohmic resistance of a film of gas under high pressure, covering the electrode. The properties of transfer resistance were described, and an explanation given of the function of platinising electrodes for conductivity determinations.

Under the same conditions, overvoltage usually, but not always, appears. This is due to the formation of compounds of the liberated gas with the material of the electrode, under the influence of the very high pressures present. The properties of overvoltage are briefly described. Valve action occurs when the anodic compound is insoluble in the electrolyte, and an electrical insulator, forming a covering film which is permeable to hydrogen ions but impermeable to the anions present. Continuing further, he stated that passivity occurs when the anodic compound is insoluble in the electrolyte, and is also an electrical conductor.

The Junior Institution of Engineers.

Col. Sir Henry George Lyons, F.R.S., D.Sc., F.Inst.P., F.R.A.S. (Director and Secretary of the Science Museum), has accepted the invitation of the Council of the Institution to become President in succession to Sir Ernest William Moir, Bart., M.Inst.C.E., and his induction will take place at a meeting to be held on December 12, at the Royal Society of Arts, on which occasion he will deliver his address.

The Institute of Marine Engineers.

THE inaugural meeting of the Institute of Marine Engineers attracted a good attendance on September 23, at which the presidential address was delivered by the new President, Lt.-Comdr. Sir August B. T. Cayzer, Bart., R.N. (Ret.). The subject of his address concerned developments made in marine engineering. Brief reference was made to various stages in the advance made, from the simple horizontal type of steam engine to the important part played by the steam turbine in recent years. The advantage of reciprocating engines, with the addition of a Baner-Wach exhaust turbine, for increasing speed or reducing fuel consumption, was emphasised. This was carried a stage further in vessels fitted with auxiliary electric drive. In this type the exhaust steam from the lower pressure cylinder in passing through the turbine, operated an electric generator, and the power was transmitted to the shafting and surplus power used for driving auxiliary machinery.

Considerable progress has also been made with the turbo-electric drive, which has been adopted for many vessels, and is reported upon favourably. The development in the construction of boilers of increased pressure has been made during recent years as a result of much thought, but he did not believe that very high boiler pressures can become common for many years. These high pressures are only obtained by the water-tube type of boiler and water possessing a high degree of purity is necessary. This involves difficulties which are not yet overcome. He commented on the progress of internal combustion engines, and suggested that steam engines should not be superseded by oil engines until we are able to provide the fuel suitable for internal combustion engines. The value of the distillation process in giving about 60% oil from coal treated offers a promising solution to this important problem. In the struggle for supremacy between various types of engines, and the development taking place to render each more economical in the consumption of fuel for power developed, coupled with the addition of auxiliary machinery for various purposes, the main installation to-day is more complicated than that in use 20 or 30 years ago. All these additions and the developments in marine engines and boilers call for more intensive knowledge on the part of the engineers in charge of such equipment, and the education of the marine engineer must necessarily embrace a much wider field than formerly. In Sir August's estimation superintendents and technical experts have proved themselves equal to demands made upon them.

Forthcoming Activities of the Institute of Metals.

A full programme for the winter session has just been issued by the Institute of Metals. This includes over forty meetings, to be held in metallurgical centres throughout England, Scotland, and Wales. The programmes of the various sections have been drawn up to meet the special needs of local industries.

Among the subjects dealt with are metal sand alloys of the future, metallurgy of some of the rarer metals, magnesium alloy castings, gases in metals, the extraction of copper, chromium plating, the applications of nickel in industry, unsoundness in metals, wire drawing, and applications of copper to the building trade. Works visits are also announced as well as practical demonstrations of metal working in the lecture hall. The President of the Institute, Dr. Richard Seligman, will read the opening paper before the London Section on "Some Non-Ferrous Metals in Chemical Engineering," and will also contribute, in Glasgow, to an "Aluminium Review" that has been arranged by the Scottish Section.

Next year's autumn meeting, it is announced, will take place in Zürich, and for 1932 a visit of members is being arranged to Canada and the United States. In connection with the American meeting, special Bankers' Order Forms gave been printed by the Institute, whereby the major portion of the cost to a member of the visit may be paid on the "instalment plan," the amount payable being, approximately, £4 per month. Members requiring copies of the Bankers' Order Form should apply to the Secretary, Mr. G. Shaw Scott, M.Sc., 36, Victoria Street, London, S.W. 1.

Aluminium Sheet Production

(Continued)

By Robert J. Anderson, D.Sc.

Sizes and Gauges. Sheet Tempers and Heat-Treated Alloys.

In a general sense, aluminium and aluminium-alloy sheet products are produced in any gauge and size within certain limits conditioned by the ingot-mould and rolling equipment available, the tonnage involved, and standard rolling practice. Normal rolling practice corresponds to specific ranges of thickness and sizes, as will be shown below, but if a sufficient tonnage of an "out" size or gauge is asked for, it may be feasible for the sheet producer to alter standard practice so as to roll what is wanted.

Sizes, Gauges and Tolerances.

Ordinarily, the limiting range of gauge (thickness) depends upon the temper, size, and the kind of sheet—i.e., whether flat or coil,—and whether aluminium or some alloy. If the standard rolling ingots made in a mill weigh 85, 100, or 135 lb., then obviously the weight of individual sheets or coils that can be rolled is limited—unless, of course, larger moulds are installed. The range of possible sizes for the heat-treatable alloys rolled from an ingot of given weight is less than in the case of aluminium, because of the greater normal percentage of scrap loss with the alloy. Unfortunately, aluminium sheet is not made in a complete and definite line of standard sizes. The bulk of production is for sizes sheared to definite dimensions as per order. In the United States some warehouse distributors of aluminium sheet list a large number of standard sizes as being carried in stock, but according to some consumers such sizes are rarely available when ordered. Typical sizes listed include the following:—24 × 36 in., 18 × 36 in., 12 × 72 in., 24 × 72 in., 36 × 96 in., 36 × 144 in., and 60 × 120 in. for aluminium sheet; coil widths run 12 in., 18 in., 20 in., and 24 in. Typical standard sheet sizes listed by The British Aluminium Co., Ltd., are the following:—3 × 6 ft., 3 × 8 ft., 4 × 8 ft., and 4 × 12 ft. Standard sizes of heat-treated alloy sheets are listed by warehouse distributors.

In American practice aluminium and aluminium-alloy sheet are produced in definite thicknesses, corresponding to the Brown and Sharpe (American wire) gauge standard. The gauge numbers form a geometrical progression of thicknesses, each thickness being the same percentage of the next heaviest gauge. Thus, 18-gauge is 0.0403-in. thick; 19-gauge is 0.0359-in. thick, or 89% of 18-gauge. 20-gauge is 0.0320-in. thick, or 89% of 19-gauge; and so on. In passing, it may be said that in certain rolling operations on aluminium sheet the metal may be reduced one gauge number in thickness per pass. Table 4 gives the Brown and Sharpe gauge numbers, corresponding thickness in inch, and weight in pounds per square foot for aluminium sheet. In England aluminium sheet is rolled in thicknesses corresponding to the Standard Wire Gauge classification. On the Continent sheets are not rolled to so-called gauge classification, but to specific thicknesses in millimetres. Sheet is often produced to specific thicknesses measured in thousandths of an inch, without reference to any gauge classification.

Coiled Sheet.—Coiled sheet (coils) is not made thicker than 10-gauge (0.102 in.) in aluminium; this applies to all tempers. In heat-treatable alloys the thickest coiled sheet is usually 12-gauge. In aluminium the thinnest coil that is ordinarily made in any temper is 36-gauge (0.005 in.). By definition material lighter than 36-gauge is classed as foil. The normal limiting thickness of heat-treated alloy coil is 30-gauge. The lightest gauge that can be made

with normal practice in 2 S or 3 S depends upon the temper. Thus, in the production of intermediate tempers by cold rolling after annealing, it is necessary to reduce the sheet by a certain minimum amount of thickness on the first pass through the rolls in order to make good material. Consequently, it is impractical to roll an intermediate temper in any gauge in cases where the difference in thickness between the gauge at annealing and the finished gauge is less than this minimum amount of thickness (reduction).

TABLE 4.

BROWN AND SHARPE GAUGE NUMBER, CORRESPONDING THICKNESS IN INCH, AND WEIGHT IN POUNDS PER SQUARE FOOT OF ALUMINIUM SHEET.

Brown and Sharpe Gauge No.	Thickness, in Inch.	Weight, Lb. per Sq. Ft.	Brown and Sharpe Gauge No.	Thickness, in Inch.	Weight, Lb. per Sq. Ft.
0000	0.46000	6.406	19	0.035890	0.4998
000	0.40964	5.704	20	0.031961	0.4450
00	0.36480	5.080	21	0.028462	0.3964
0	0.32486	4.524	22	0.025347	0.3530
1	0.28930	4.029	23	0.022571	0.3143
2	0.25763	3.588	24	0.020100	0.2798
3	0.22942	3.195	25	0.017900	0.2492
4	0.20431	2.845	26	0.015940	0.2219
5	0.18194	2.534	27	0.014195	0.1976
6	0.16202	2.256	28	0.012641	0.1760
7	0.14428	2.009	29	0.011257	0.1567
8	0.12849	1.789	30	0.010025	0.1396
9	0.11443	1.594	31	0.008928	0.1244
10	0.10189	1.418	32	0.007950	0.1107
11	0.090742	1.264	33	0.007080	0.09854
12	0.080808	1.126	34	0.006304	0.08778
13	0.071961	1.002	35	0.005614	0.07817
14	0.064084	0.8924	36	0.005000	0.06962
15	0.057068	0.7946	37	0.004453	0.06201
16	0.050820	0.7078	38	0.003965	0.05521
17	0.045257	0.6302	39	0.003531	0.04917
18	0.040303	0.5612	40	0.003144	0.04378

It is accordingly a matter of regret to operators when consumers order very light gauge sheet in the quarter-hard temper. This temper cannot be worked satisfactorily in sheet lighter than 24-gauge; half-hard sheet is inadvisable in sheet lighter than about 30-gauge. The other standard tempers, including soft and hard, are satisfactory for material from 10- to 36-gauge. The commercial limitations of thickness for coiled sheet in different tempers are given in Table 5; these limitations apply also to flat sheet.

The width of coil sheet supplied depends in part on the gauge, and in part on the width of rolls in the available mills. The usual widths of aluminium coil sheet range from up to 12 in. for 34- to 36-gauge to 21 in. for 10- to 18-gauge. Coil as narrow as 1-in. wide is slit. Wide coil is, however, regularly supplied, e.g., as follows:—Up to and including 22-gauge, 25 in. wide; 23- to 24-gauge, 20 in. wide; and 25- to 26-gauge, 16 in. wide. In some mills coil is made as wide as 35 in. in 10- to 18-gauge; coil 48 in. wide has been made. Of course the width possible with reasonable thickness tolerances is less the lighter the gauge. The foregoing refers to both 2 S and 3 S, rolled on ordinary two-high mills. If aluminium strip is rolled on four-high mills, as is now being done in steel practice, much wider widths with small variation in thickness across the strip is possible. Table 6 gives the usual widths made in 2 S and 3 S coil sheet as conditioned by the gauge thickness.

The widths given may be referred to as "standard." In the case of heat-treated coil sheet, narrower widths are usually rolled for a given gauge; this is due to the scrap loss caused by cracking in at the edges. Width of 15 to 16 in. is the usual maximum made in this class of material. The normal thickness tolerance for aluminium coil, 30- to 36-gauge up to 12 in. wide, is ± 0.001 in., and increases up to 0.003 in. for 10- to 18-gauge. The length and weight of aluminium coil varies, depending upon the width, gauge, and weight of ingot rolled, as well as upon the recovery in rolling. Weights of 30 to 60 lb. are usual in average run of material. Coil weights and lengths will be discussed more fully in a later article. Typical weights of ingots rolled in American practice are 75 lb., 85 lb., 100 lb., and 125 lb. Very long coils, in narrow widths, weighing around 250 lb., are made by welding a number of coils together and then winding. Flattened strips made from aluminium coils are not usually supplied in thicknesses lighter than

TABLE 5.
GAUGE THICKNESS OF ALUMINIUM SHEET, AS AFFECTED BY TEMPER.

Temper.	Thickness.	
	Limiting Range, Brown and Sharpe Gauge Number.	Limiting Range, Thickness, In.
Soft	10 to 36	0.102 to 0.005
Quarter hard	10 to 23	0.102 to 0.0226
Half hard	10 to 30	0.102 to 0.010
Threequarters hard	10 to 36	0.102 to 0.005
Hard	10 to 36	0.102 to 0.005

TABLE 6.
WIDTHS OF ALUMINIUM COIL SHEET AND CORRESPONDING GAUGE THICKNESS.

Thickness.		Limiting Width, In.
Brown and Sharpe Gauge Number.	In.	
10 to 17	0.102 to 0.0453	21
Thinner than 17 to 22	0.0452 to 0.0253	18
Thinner than 22 to 25	0.0252 to 0.0179	16
Thinner than 25 to 28	0.0178 to 0.0126	15
Thinner than 28 to 33	0.0125 to 0.0071	14
Thinner than 33	0.0070 and less	12

24-gauge. The maximum length of coils made in heat-treated aluminium alloys varies with the factors mentioned above for aluminium coils and also with the temper—*i.e.*, whether annealed or heat-treated. Thus, the limitations as to coil sizes as given by the Aluminium Co. of America¹¹ for heat-treated material are as shown in Table 7. These sizes may be exceeded.

Flat Sheet.—The following remarks apply in a general way both to bright flat sheet and grey plate in 2 S and 3 S. The range of thickness of flat sheet is the same as for coil. Usual widths run up to about 60 in., while lengths run up to 180 in. Widths up to 84 in. are commercial in some mills, and sheet 106 in. wide has been made. Preferably, from the point of view of easy handling in rolling, a single sheet should weigh less than 250 lb., and be less than 15 ft. long. In the production of the harder tempers in thick sheet, *e.g.*, 6- to 10-gauge, special rolling practice is necessary. Regular widths furnished in flat sheet decrease with the lighter gauges, *e.g.*, up to 60 in. wide for sheet 20-gauge and heavier down to 24-in. wide for 34-gauge, as shown in Table 8.

Regular lengths furnished decrease with lighter gauges—*e.g.*, from, say, 144 in. long for 18-gauge and heavier to 96 in. for 24-gauge, as shown in Table 8. The wider the sheet the greater the excess of thickness in the centre as compared with the edges. Grey plate is normally made

in thicknesses from $\frac{1}{8}$ in. to 20-gauge, the greater part of the production being in the heavier gauges, such as 12-, 14-, and 16-gauge. Sheets as large as 48 \times 144 in. in the heavier gauges, and 28 \times 144 in. in the lighter gauges, are being produced in heat-treated alloys. The usual

TABLE 7.
USUAL LIMITING SIZES OF COILED SHEET MADE IN HEAT-TREATED ALUMINIUM ALLOYS.

Brown and Sharpe Gauge Number.	Thickness, In.	Maximum Width, In.	Maximum Length, Ft.	
			Heat-treated Temper.	Annealed Temper.
12 to 13	0.081 to 0.072	16	25	30
Thinner than 13 to 15	0.071 to 0.057	16	34	40
Thinner than 15 to 18	0.056 to 0.040	16	45	50
Thinner than 18 to 21	0.039 to 0.029	16	50	60
Thinner than 21 to 25	0.028 to 0.018	15	65	75
Thinner than 25 to 29 inclusive	0.017 to 0.011	15	85	100

thickness tolerances that are met commercially in aluminium sheet, both flat and coil, are indicated in Table 9, which are the latest tentative specifications of the American Society for Testing Materials. Closer tolerances are held in practice on certain grades and sizes of special sheet—*e.g.*, radio sheet and lithographic plate. Various specifications have been drawn up covering gauge tolerances. According to some specifications, to ensure accuracy of thickness the sheets are to be weighed, and the weight is required not to differ more than 5% from the weight calculated from the actual area of the sheet and the specified gauge, on the basis of standard density value for aluminium of the composition specified. Table 10 gives the thickness tolerances as tentatively specified by the American Society for Testing Materials for duralumin sheet.

Plate.—The commercial thickness range of plate is from about $\frac{1}{8}$ in. to 1 in. The maximum weight of a single plate depends upon the size of the ingot mould available while the maximum width and length depend upon the ingot, thickness of plate, and available mills. Plates are usually made in various sizes up to weight of around 500 lb., width of 105 in., and length of 25 ft. Plate may be produced thicker than 1 in. if required. Single plates weighing as much as 1,750 lb. have been rolled. Thickness

TABLE 8.
USUAL LIMITING WIDTHS AND LENGTHS OF FLAT SHEET IN ALUMINIUM, AS AFFECTED BY THE THICKNESS.

Brown and Sharpe Gauge Number.	Thickness.	Width or Length Limit, In.	
		In.	Limit.
10 to 20	Widths.	0.102 to 0.032	60
Thinner than 20 to 24	0.031 to 0.020	48	
Thinner than 24 to 29	0.019 to 0.011	30	
Thinner than 29 to 32	0.010 to 0.008	26	
Thinner than 32	0.007 and less	24	
18 and thicker	Lengths.	0.040 and more	144
Thinner than 18 to 20	0.039 to 0.032	120	
Thinner than 20 to 24	0.031 to 0.020	96	
Thinner than 24	0.019 and less	Random 36 to 72	

tolerance on plate is about $\pm 5\%$ of the nominal thickness.

Circles.—While circles may be, and are, made both from bright flat sheet and grey plate, the bulk of the production in the United States is from coiled sheet.

The general remarks made above regarding aluminium coil apply to circles. Output of heat-treated alloys in circle form is small. Usual diameters of circles range from about 6 to 24 in., although smaller sizes are regularly

TABLE 9.
PERMISSIBLE VARIATIONS IN THICKNESS OF ALUMINIUM SHEET.*

Brown and Sharpe Gauge Number.	Thickness.	Tolerance in Thickness, In.		
		20 in. in Width and Narrower	Over 20 in. to 36 in. inclusive in Width	Over 36 in. to 60 in. inclusive in Width
2 to 3	0.258 to 0.229	± 0.007	± 0.008	± 0.009
Thinner than 3 to 9	0.229 to 0.114	± 0.005	± 0.006	± 0.007
Thinner than 9 to 13	0.113 to 0.072	± 0.003	± 0.0035	± 0.004
Thinner than 13 to 21	0.071 to 0.028	± 0.0025	± 0.0025	± 0.003
Thinner than 21 to 24	0.027 to 0.020	± 0.002	± 0.002	± 0.003
Thinner than 24 to 27	0.019 to 0.014	± 0.002	± 0.002	± 0.002
Thinner than 27	0.013 and less	± 0.0015	± 0.0015	± 0.0015

* Tentative specifications of the American Society for Testing Materials, 1930.

made, and there is some small production of circles up to 7 ft. in diameter. The bulk of the circle stock goes for the manufacture of kitchen cooking utensils. Standard circle-blanking dies vary in diameter by $\frac{1}{8}$ in. over a considerable range. Large circles—e.g., more than 4 ft. in diameter—are not ordinarily made lighter than 18-gauge. Circles of any diameter are not normally furnished lighter than 30-gauge.

Sheet Temps.

The so-called temps of aluminium sheet, and of non-heat-treatable alloy sheet, are produced by annealing and the cold working of rolling. The system of temper classification is based on the tensile properties and hardness corresponding to particular mill practice. Temps in aluminium sheet and certain of the non-heat-treatable alloys include several intermediate hardnesses, soft, and full-hard. The temps of sheet made in heat-treatable alloys include soft (annealed), as quenched (and air-aged), and so called fully heat-treated—i.e., quenched and air-aged, or quenched and aged, at some elevated temperature.

Aluminium Sheet.—Dead-soft aluminium sheet is produced by annealing full-hard material. The full-hard sheet is produced by the cold working of rolling, it being understood ordinarily that the material has been reduced by

TABLE 10.
PERMISSIBLE VARIATIONS IN THICKNESS OF DURALUMIN SHEET.*

Brown and Sharpe Gauge Number.	Thickness.	Tolerance in Thickness, In.		
		18 in. in Width and Narrower	Over 18 in. to 36 in. inclusive in Width	Over 36 in. in Width.
Thicker than 11	0.092 and more	$\pm 5\%$ of Sheet Thickness	$\pm 5\%$ of Sheet Thickness	$\pm 5\%$ of Sheet Thickness
11 to 13	0.091 to 0.072	± 0.003	± 0.003	± 0.004s
14 to 15	0.064 to 0.057	± 0.0025	± 0.003	± 0.004
16 to 18	0.051 to 0.040	± 0.002	± 0.0025	± 0.003
19 to 28	0.036 to 0.013	± 0.0015	± 0.002	± 0.0025

* Tentative specifications of the American Society for Testing Materials, 1930.

an amount equivalent to 12 gauge numbers after annealing. Intermediate temps between dead-soft and full-hard are produced by specific rolling reductions after annealing.

There is practically no widening of sheet on rolling, and hence the production of intermediate temps depends upon the reduction in thickness, since the change in cross-sectional area is proportional to the change in gauge. While it is possible to produce a sheet of any thickness having practically any desired temper, in practice only certain temps are made as standard in the heavier gauges. Mention has previously been made of the undesirability of rolling light-gauge sheet in the quarter-hard temper. The system of temper classification is a convenient means of indicating specific mechanical properties, and hence degrees of workability. Most industrial requirements are met by the following temps:—

1. Dead-soft.
2. Quarter-hard.
3. Half-hard.
4. Three-quarters-hard.
5. Full-hard.

However, certain intermediate temps other than those just given are made to meet special requirements.

As indicated previously, commercial aluminium sheet is referred to as 2 S, while the alloy containing about 1.25% manganese (remainder commercial aluminium) is called 3 S. Dead-soft sheet, produced by suitable annealing of hard-rolled sheet, is termed 2 SO or 3 SO, depending upon the material in question. Hard-rolled sheet is termed 2 SH or 3 SH. The suffix O added to 2 S or 3 S means fully annealed, while H means hard-rolled. The intermediate temps

TABLE 11.
SCLEROSCOPE-HARDNESS* VALUES CORRESPONDING TO DIFFERENT TEMPS OF 2 S AND 3 S SHEET.

Temper Designation.	Range of Hardness Values Corresponding to Gauge† Thickness		
	14-gauge.	20-gauge.	26-gauge.
2 S Sheet.			
2 S0 (dead soft)	4 to 7	4 to 7	4 to 7
2 S2 (quarter hard)	9 to 15	8 to 14	7 to 13
2 S4 (half hard)	11 to 17	9 to 16	8 to 14
2 S6	12 to 18	11 to 17	9 to 15
2 S8 (threequartershard)	13 to 19	12 to 18	10 to 16
2 S10	14 to 20	13 to 19	11 to 17
2 SH (full hard)	20 to 24	21 to 25	22 to 27
3 S Sheet.			
3 S0 (dead soft)	8 to 11	7 to 10	7 to 10
3 S2 (quarter hard)	14 to 20	12 to 18	11 to 17
3 S4 (half hard)	16 to 22	13 to 19	12 to 18
3 S6	18 to 24	14 to 20	13 to 19
3 S8 (threequartershard)	19 to 25	15 to 21	13 to 19
3 S10	20 to 26	16 to 22	14 to 20
3 SH (full hard)	23 to 29	22 to 28	22 to 28

* Magnifier hammer. † Brown and Sharpe gauge.

between soft and hard are identified by numerical suffixes. Thus, quarter-hard is called 2 S2, or 3 S2, half-hard is 2 S4 or 3 S4, and threequarters-hard is 2 S8 or 3 S8. This system of temper designation was designed by the Aluminium Co. of America, and it is used generally as a means of identifying and specifying aluminium sheet in the United States.

The system of intermediate temper classification and designation may be explained as follows:—The average tensile strength of sheet products that are four numbers hard—i.e., 2 S4 or 3 S4—is greater than that of dead-soft sheet of the same gauge by about one-half the difference between the average strengths of dead-soft and full-hard sheet; hence, such sheet is termed half-hard. Thus, dead-soft 2 S sheet has tensile strength of about 12,000 lb. per sq. in. (minimum), and the strength of full-hard sheet is about 22,000 lb. (minimum). One-half the difference between these values is 5,000 lb.; adding this to 12,000 lb. gives 17,000 lb. This latter figure is a usual value for the tensile strength of 2 S4 (half-hard) sheet. In the same way 2 S2 and 3 S2 are quarter hard, and 2 S8 and 3 S8 are threequarters-hard—as referred to the tensile strengths.

In the production of flat sheet the gauge number reduction for intermediate tempers subsequent to annealing is as follows:—Two gauge numbers for quarter-hard, four gauge numbers for half-hard, and eight gauge numbers for threequarters-hard. As mentioned above, full-hard sheet is reduced at least 12 gauge numbers after annealing. In British practice the temper "medium-soft" corresponds to the American half-hard, and "medium-hard" corresponds to threequarters-hard. It is found in running coils, as contrasted with flat sheet, that there are small differences in the tensile strengths of the two products for a given intermediate temper—*i.e.*, if the coil sheet is made in, say, 2 S4, the strength is somewhat different than when flat sheet is made in the same temper by reducing four gauge numbers after annealing. In other words, in order to make the two classes of material the same as to mechanical properties, it is necessary to vary the gauge reduction of the coil somewhat. The reason for this is evidently ascribable to the difference in the draft per pass on sheet mills as compared with coil mills.

Table 11 gives the Shore scleroscope-hardness values of 2 S and 3 S sheet in different tempers. These figures show an average range of values for commercial material. The scleroscope hardness of aluminium sheet will be discussed at length in a later article. As will be noticed from Table 11, and as will be seen in greater detail later when the mechanical properties of aluminium sheet are discussed at length, there is some overlapping in the properties of different tempers. Hence, the specification of such tempers as 2 S6 and 2 S10, and more especially of odd temper numbers, is an unnecessary refinement which in some cases cannot be met. Such a temper specification as 2 S1—used often to indicate to the rolling mill that the smallest possible reduction in thickness should be run in finishing to gauge after annealing—is almost meaningless in the lighter gauges. It is not practical to roll sheet with a reduction of one gauge number, particularly in the lighter gauges. Even if it were practical so to roll, the tensile strength of the resultant product would be expected to fall in the range allowable for 2 S0 or 2 S2. Some odd or unusual temper number may give better performance in the draw-press than a standard temper. Thus, a fair tonnage of coil is being run at the present time in 2 S1. It is the general practice of sheet producers to discourage the use of odd-number temper designations, and to induce customers to specify standard tempers. Still, when consumers insist upon sheet being reduced a specific number of gauge numbers, or being rolled in some special way, their demands will usually be met.

Heat-Treated Alloy Sheet.

As previously indicated, sheet made of heat-treatable aluminium alloys is usually furnished in three so-called tempers, *viz.*, (1) annealed, (2) as quenched and air-aged, and (3) quenched and aged. Alloy sheet may also be furnished as rolled (*i.e.*, hard) to consumers who do their own heat-treating. In some cases fully heat-treated sheet may be further reduced by cold rolling, giving a stronger and harder material. Also, the alloy sheet is occasionally furnished in some tempers corresponding to the tempers described previously for aluminium sheet, *e.g.*, annealed alloy sheet may be reduced two gauge numbers by cold working. There is no good reason for using sheet in this latter condition.

Referring to the heat-treatable alloys made by the Aluminum Co. of America in sheet form, the magnesium-silicide alloy 51 S is supplied regularly in three tempers, designated 51 S0, 51 SW, and 51 ST. Here O means annealed, W means quenched, and T means quenched and aged at moderately elevated temperature. This alloy, after quenching, will age-harden spontaneously on standing in air. Higher strength is obtainable by artificial ageing. The alloy 25 S is furnished in the same tempers as 51 S. Duralumin (17 S) is furnished in the two tempers 17 S0 and 17 ST; this alloy age-harden fully on standing in the

air after quenching. Alloys A17 S and B17 S are supplied in the tempers O and T, and alloy C17 S is supplied in the tempers O, W, and T. Any of these alloys may be supplied as hard rolled.

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In the second article of this series the raw materials used in the production of aluminium and aluminium-alloy sheet will be discussed.

Catalogues and Other Publications.

Al-dur-bra is one of the most interesting developments of modern metallurgical research in that it marks an outstanding achievement in the quest for materials highly resistant to corrosion. The name is applied to an aluminium brass cast by the Durville process. It is covered by a patent, and Charles Clifford and Son, Ltd., of Birmingham, manufacture it under license. A brochure dealing with this alloy has been issued by this firm, in which the mechanical and working properties, as well as its corrosion-resisting qualities, are technically discussed. A copy of this brochure is available on application to this firm.

Modern methods of tempering consist in reheating the steel either in a bath of oil, lead, or salt, or in an air tempering oven. We have received a brochure dealing with air tempering ovens with forced air circulation. Particulars are given of one of these ovens which show the remarkably high efficiency of 89% which has been obtained by means of the special form of fan incorporated in the oven. This fan increases the rate of heating, and effects considerable saving in running costs. These ovens are made in various sizes by Wild-Barfield Electric Furnaces, Ltd., Elecfurn Works, Holloway, London, W. 7, and all interested should read the information contained in this brochure.

We have received an attractive brochure which contains information respecting the use of "Holfos" bronze for many purposes, particularly for worm gears subject to heavy wear, and also chill cast bars in two grades—*viz.*, phosphor bronze B. 8 specification and special "Holfos" bronze. This latter bronze is a product of research in the works laboratories, and is produced under exacting conditions. Those interested can have a copy on application to John Holroyd and Co., Ltd., Perseverance Works, Milnrow.

Malleable Cast Iron

By J. V. Murray,

PART IV.

Annealing in the Whiteheart Process involves decarbonising and graphitisation.

THE annealing of hard white iron castings calls for considerable metallurgical knowledge if the castings are to be really malleable and have no hard spots. Castings may be very soft after annealing and yield to the drill in machining very easily, but a slight blow from a hammer may break them into two parts. Annealing is a term very loosely used to denote heat-treatments in iron and steel. In blackheart annealing the process is one of graphitisation generally, but in the whiteheart process it is a dual one—that of decarbonising and graphitisation. The blackheart process is employed chiefly in America, and was the invention of an Englishman, Seth Boyden.

Preparations for the Anneal.—The castings are collected from the moulders, and are taken to the sorting department, where the articles are examined for defects. During the examination the inspector notes any signs of a mottle at the junction of the gate and the castings. When the gates are knocked off hot—*e.g.*, heavy work practice,—oxidation tints blue the junction, and inspection by this method will not do. In this case a button is cast in green sand. This button is about 3 in. in diameter, and may be notched with a V on either side. The button, when cold, is fractured with a sledge, and the mottle is easily seen. Should any mottle be detected the article is rejected. The mottle is

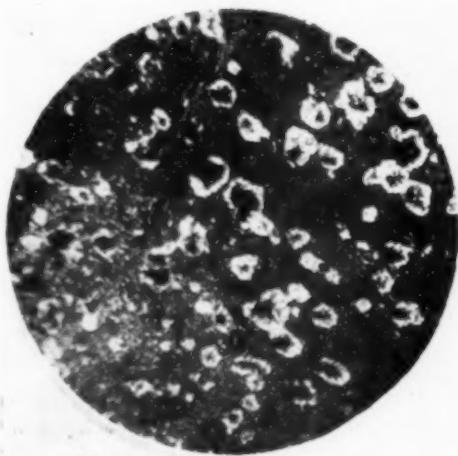


Fig. 11.—One Day's Anneal. Composition—Si 0.50, S 0.131, P 0.078, Mn 0.20 \times 100. Picric Acid Etch.

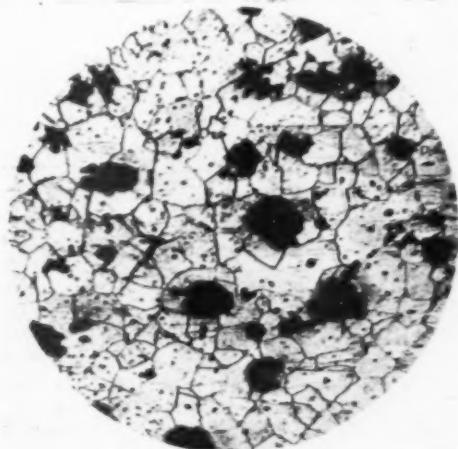


Fig. 12.—Fully Annealed Whiteheart Malleable. Same Composition as Fig. 11. Etched in 2% Picric Acid, 2% Nitric Acid in Alcohol. \times 100.

The process was due to two reasons, the first being the high manganese pig iron, and the other a lack of red hematite ore.

The whiteheart process is due to the French scientist Reamur, who experimented with hard white irons, which were required for the French soldiery in their equipment, such articles as bits, stirrups, spurs, and buckles being the chief requirements. He found that these articles when packed in red powdered hematite ore and heated for a few days became soft, and when broken had a whiteheart core. Hence the term "whiteheart," this white fracture, as is well known now, being due to the fact that nearly all the graphitised carbon was removed, leaving any carbon in the combined state. This helped to make the fracture white. The process was taken up with avidity in England, and Walsall, being the home of the saddlery trade, became the centre of production in malleable castings. It has remained so ever since. In hardware trades and agricultural iron-work, malleable cast iron still holds its own. In those days the knowledge was chiefly empirical, but with the advent of metallurgical science the product became very much superior to the old material, and in the general engineering trades malleable castings are now indispensable. At the present time engineers demand a good strong article, equal to mild steel, and are getting it, too. The present article gives an account of the process of annealing to produce castings equal to the B.E.S.A. specification.

caused by primary graphite, and castings possessing this will not become malleable by annealing. In fact, they become rotten.

The good castings are now either barreled or sand-blasted. This removes the adhering sand, makes them clean, but hides any traces of greyness. Hence the necessity of examining the castings prior to this. They are next passed to the annealing department for heat-treatment.

Annealing by the Whiteheart Process.

The castings are now carefully packed in "cans" in a mixture of ores. A mixing of one part of new red ore to four of black ore is made in a mechanical mixer. This is riddled with a fine sieve to allow the dust to fall away. It is then ready for use. Fine dust is not allowed in the cans because it contains much silica, which slags on to any oxide skin and makes the castings dirty. The packing of cans is almost a fine art, each article being scrupulously placed in position to ensure economy in space and in ore. The annealing cans are of various shapes and sizes, the most common being circular, 12 in. diameter and about the same height. Large articles call for special shapes, but round and oblong are the usual types. The cans are made from "can metal," this being the foundry term for rejected annealed castings. Quite a well-grounded complaint could be lodged against the quality of the cans, some lasting six to eight heats, whilst new cans sometimes fail in the initial

one. The cans are filled and well luted with black sand and a little fireclay for binding. They are porous to some extent, but should exclude penetration by furnace gases. When the furnace gases do get inside, the castings will pick up sulphur, become blue, and may oxidise the castings to such an extent as to ruin them by sealing badly.

The furnaces are rectangular, about 6 ft. high, and may hold from 40 cans to 170. They may be, and usually are, fired with hard coal, although gas and oil are both successfully used. The grates are on either side of the furnace. Gas is used on the regenerator principle, whilst oil burners are inserted near the top. Flues may take away the products of combustion at the sides, top, or bottom. The American continuous furnace has yet to make its successful debut in this country for annealing whiteheart malleable castings.

The piling of cans calls for intelligence. These should be placed about 2 in. from the walls, and a small space left between each pile for the heat to diffuse properly. When full, the front of the furnace is built up with fire-bricks, except for a small space left for the annealer to watch the cans. This is closed with a loose firebrick, which fits into the space. The furnace should be controlled pyrometrically, the finest method, in the author's opinion, being the thermo-couple with the automatic recorder.

Annealing.—The furnace is now lit up, and the most important part commences. Heat must be diffused gently through the mass. An increase of 24° C. per hour is good practice. At least 40 hours should elapse before the annealing temperature of 950° C. is reached. This will prevent peeling, and will also prevent all the carbon being removed just on the outside. The diffusion of carbon is gradual, and much more is removed by gentle methods than by forcing. From the attaining of the annealing temperature about six days should elapse. Temperature should never exceed 980°, for reasons which will be explained later. The furnace should now be insulated as far as possible from air, and should cool as slowly as possible to 360° C., about 10° per hour being good practice. The front bricks may then be removed, and the furnace left to cool overnight. The cans are withdrawn from the furnace, overturned, and the articles and the ore removed by striking the cans on the side or bottom with a sledge hammer. The castings should be slightly yellow in colour if the practice has been successful. These are sent to the cleaning department for barrelling or sandblasting again, whilst the ore is returned to the used-ore dump for further use when required. All the red-coloured ore has been transformed from ferric oxide (Fe_2O_3) into its magnetic higher oxide (Fe_3O_4) and has become blue. The cans, which have become thickly coated with scale, are cleaned by hammering and returned to the can store. The scalings of the cans is a raw material of the blast furnace, to whom it is sold. Such is a brief account of the practical side of the work.

The Chemistry of the Process.

In discussing the chemical changes, one must consider the condition of the castings. The castings are super-cooled, and they are more than saturated in carbon. As heat is applied, the tendency will be for the castings to revert to a state of equilibrium, or to the condition which was prevented by the cooling of them. The pressure will be greater at the lower temperature than at the higher, and also greater near the outer surfaces than in the interior. This, the first effect of the heat, may cause the castings to crack. The carbon in the almost amorphous structure near the edge will pass out as this is super-saturated. A dense mass of austenite gathers towards the outside, but the internal mass will decompose according to the equation,



which is exactly what happens in the blackheart anneal. If cooled, it will be found that the fracture is a typical picture frame and very black in the centre, with a crystalline frame. This crystalline frame is found in all low-temperature annealed malleable castings—i.e., about

700–800° C. Further, low temperature annealing decomposes the austenitic area, and the result is a true blackheart, irrespective of chemical composition within the limits of both types. To produce whiteheart, the temperature is raised to about 980°, when more carbon is taken

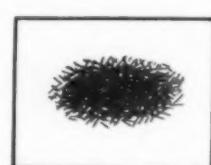


Fig. 13.—*Bull's Eye Fracture of Large Castings.*

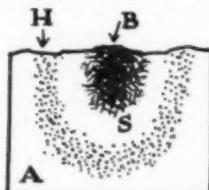
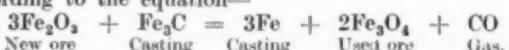


Fig. 14.—*Inner Zone Blackheart Structure.*

into solution, but the effect of the oxide packing is now felt. The oxygen of the ore combines with the carbon and, according to the equation—



The chemical position becomes more complicated.



and the following chemical reactions recur continually:—



There are mixed gases within the can, and there is no doubt that the monoxide of the carbon is the principal factor in the removal of the carbon, but it may be stated briefly:—

1. Carbon can only diffuse when in solution.
2. Carbon is removed by the oxygen in the ore.
3. The monoxide is transformed into CO_2 .
4. That pressures of CO and CO_2 within the can cause both gases to penetrate (see Fig. 15) within the metal towards the diffusing carbon.
5. The eutectoid carbide is not decomposed prior to removal.
6. The eutectic carbide is decomposed and taken into the solution again during the anneal.
7. Equilibrium is established during the later part of the anneal through the above.

During the early part of the anneal the castings are not malleable, even when the carbide has decomposed. There is a period of softening treatment which has no relation to any chemical reactions. This hardness is inherent in the metal, and is only removed by heat. Thus, there is a



Fig. 15.—*Microphotograph of Fig. 14, showing Four Zones in Malleable.*

hardness due to the presence of the carbide, and a secondary yet important hardness, possessed by the metal. The removal of this latter is the true anneal, and the stages of the malleableising are—

1. Graphitisation.

2. Softening.

3. Decarbonisation.

Nos. 1 and 2 being the blackheart, and 1, 2, and 3 being the whiteheart processes.

It has been stated that the structure may be blackheart or whiteheart according to the temperature of the anneal. Fig. 11 shows the structure of a casting after one day's anneal. The fracture was quite black. It can be seen that there is very little free carbide present. The casting was very hard and brittle. Fig. 12 shows a much larger casting of the same composition with a pure blackheart structure. This also had a black fracture. The annealing at a lower temperature had not produced the whiteheart, but the whole of the carbide had been decomposed, and a good blackheart structure with the composition stated had resulted. The raising of the temperature to 960° would have transformed this casting. More carbon would be taken into solution, and equilibrium being established, a whiteheart would present itself. It has been stated by many writers that large articles in whiteheart cannot be made, and that there is always too much carbide in or near the centre. Whilst the first portion of this statement

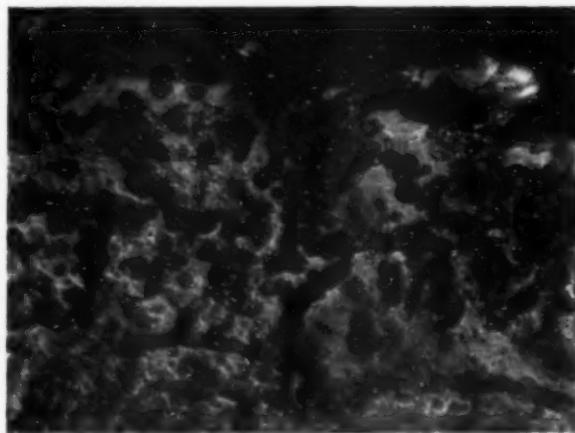


Fig. 16.—Effect of High Temperature : Severe Oxygen Penetration.

is true, the second is untrue. The structure of a large whiteheart casting in or near the centre should be ferrite and nodular carbon. In other words, the outer zone is whiteheart and the centre is blackheart. The fracture of such a casting should be the bull's eye, as shown in Fig. 13. (The author hopes to present a paper very shortly on this important aspect of annealing malleable cast iron.) Thus, there is a soft core which will withstand shock and a tougher outer area. Should heat be applied too severely at the initial stage, another zone makes its appearance. Instead of carbon diffusing from the centre, it will diffuse from an inner zone, and the centre may not break down because it is more stable at higher temperatures, and the result may be as shown in Fig. 14. A would be ferrite, H would be a hard mass of tough, fine pearlite, S would be soft ferrite and pearlite, whilst B would still have the original structure, as cast (see Fig. 15). The correct method of producing good whiteheart is to produce the following structures and fractures, by correct heat-treatment.

1. Original structure Brittle White fracture—as cast.
2. Blackheart centre Brittle and Black fracture, hard.
3. All pearlite centre.... Softer White fracture.
4. Ferrite and pearlite ... Malleable .. Grey dirty fracture.

These fractures refer to a medium-sized casting, about $\frac{1}{4}$ in. diameter.

Practical Considerations.

Many a batch of castings has been spoiled by heating up too quickly, but often castings may be spoiled by a last firing. Successful annealing goes on until perhaps the last firing, when the annealer gives the oven a little bit extra coal for "the last one." Temperature goes up to, say, 1,000° C., and, instead of decarbonising, more nodular carbon is taken up into solution, and the castings are in a

worse condition than they were a day previous (see Fig. 16). The best treatment is to have the temperature a little lower the last two days; insulate the furnace and keep it near 800 the whole of the last firing day. The eutectoid pearlite is decomposed easier by this means, and better malleability results.

To meet the elongation tests required by the B.E.S.A., the heat-treatment should be about 20 hours at 690–700° C. at the end of the anneal. When the pearlite breaks down the elongation will go up. The bend-test values increase with it, but the tensile may decrease a little. It must not be thought that during the annealing of whiteheart malleable castings the ferric oxide decomposes and gives off oxygen. The action is purely a chemical one between the ore and the carbon in the iron. Oxygen is not given off in bulk. If it were, the castings would be "burnt." Should the oxygen come away too fiercely from the ore, the castings are peeled or penetrated locally by the gas and spoiled. Fig. 16 shows the effect of oxygen penetration at a local spot. These castings were entirely spoiled. Further annealing causes the oxygen to penetrate deeper until the whole of the castings are more or less oxidised throughout the mass. Therefore, to prevent too much oxygen penetration, the ore is diluted with spent ore. Any other inert substance would do, but it is the finest material known for leaving the metal clean, and makes no dust. The author has annealed malleable castings with many substances, such as carbonates, oxides, and pure metals, etc., but from an economic point of view oxide of iron is unequalled, and from the purely metallurgical side no results can compare with malleable castings when annealed in a proper mixture of the two iron oxides.

(To be continued.)

A Bridge Erecting Feat.

An engineering feat of considerable magnitude has recently been completed over the river Dove. It consisted in removing a steel railway bridge and replacing it with a more modern and stronger structure. Preparatory to the changing operation, the new bridge had been assembled alongside the old one. It consisted primarily of two sections, each weighing 54 tons, and between these sections fifteen 5-ton girders were riveted, the whole being made into a single span weighing 200 tons, and supported on ball bearings.

A convenient time was arranged to reduce interference with traffic to a minimum. The arrangements allowed for a twenty-four hour break, and directly the last train had passed a gang of platelayers removed the permanent way, and within two hours the steel skeleton of the old bridge was bared. The main structure was cut and the parts were lifted off the piers and removed on railway wagons, the old cross girders being cut up and shifted in turn. During this time the work of replacing the old bed-stones by new ones was accomplished, and in about 10 hours the whole of the old bridge had been removed and the task of rolling in the 200-ton new bridge commenced. This was accomplished by means of powerful winches and steam hawsers, and the track rapidly laid and connected up in ample time for the first train.

Canal Reconstruction Scheme.

A scheme for increasing the value of inland water transport is suggested and is being promoted by the Grand Union Canal Company. In effect this company propose to reconstruct their waterways in order to permit the safe passage of motor canal boats. The waterways affected stretch from Limehouse to Birmingham, a distance of about 240 miles, and the suggested reconstruction is to accommodate motor-boats 72 ft. long, 12 ft. 6 in. in beam, and with a draught of 4 ft. or 4 ft. 6 in.

The scheme, which is expected to cost more than £1,000,000 in its entirety, will involve the reconstruction of hundreds of bridges and locks, extensive dredging of the bed of the canal, and the building of concrete "banks" sufficiently strong to withstand the additional suction created by the passage of the motor craft. The time involved in carrying out this work would not be less than six years, but when completed it would have a considerable effect in quickening transportation and would influence the whole of the inland water transport system of the country.

Reviews of Current Literature.

Journal of Institute of Metals, vol. xliii.

THE latest volume of the "Journal of the Institute of Metals" is divided into two sections, the first consisting of a record of the proceedings at recent meetings of the Institute, and the other of abstracts of the world's metallurgical and engineering literature. The latter is particularly useful for enabling a quick survey to be taken of technical developments during the past six months, whilst section one contains a record of entirely original research.

The scientific papers appearing in this volume are preceded by a stimulating address by the new President, Dr. Richard Seligman, in which there are indicated the many new fields of usefulness that are open to the Institute of Metals—a body which certainly cannot be accused of failing to follow a progressive policy right from its foundation 22 years ago. A blend of the practical and the scientific is to be seen in the papers and discussions now presented. Thus, we note such titles as "The Effect of Phosphorus on Copper," "The Composition of Eutectics," "Experiments on the Influence of Gases on the Soundness of Copper Ingots," and "Atmospheric Action in Relation to Fatigue in Lead"—among a dozen other communications. Two of the latter are of special interest: Dr. T. A. Rickard's voluminous paper on "The Early Use of Metals"—which is likely to become a standard work of reference on the subject,—and Major Freeth's stimulating May lecture on "The Influence of Technique on Research."

The volume is well bound and clearly printed, and is illustrated by many line blocks and 40 plates. The "names and subjects" index contained in this volume is very thorough and increases its value considerably.

Edited by G. Shaw Scott, M.Sc. The Institute of Metals, 36, Victoria Street, S.W. 1. Price, 31s. 6d. net.

Impurities in Metals.

Their Influence on Structure and Properties.

METALS invariably contain impurities, and the influence of these impurities frequently has considerable effect on the properties of a metal or an alloy of which it forms a constituent. For scientific purposes it is possible, and generally desirable, to use metals of a very high degree of purity; but for industrial purposes the same degree of purity is not economically possible, and it is recognised and appreciated that further knowledge of the effects of these impurities leads to increased control and facilitates the ability to reproduce results. Impurities generally refer to unintentional inclusions in a metal, and are distinct from those that are definitely added or allowed to remain in the metal for some specific purpose, but for the purpose of this work the author does not distinguish between inclusions whether added intentionally or otherwise; he prefers to describe them collectively as minor constituents.

A considerable amount of valuable research work has been carried out in which the influence of minor constituents of some metals has been investigated, and the results have been instrumental in supplying information beneficial in production processes. In some instances the effect of small quantities of added elements on certain properties has been investigated in great detail, in others experience has shown certain elements to be beneficial or detrimental, and accumulated facts form a basis on which some general hypothesis can be built. In this work much of the valuable data that exists on the subject has been collected and the information arranged in a systematic manner. Evidence of the practical value of this work to users and manufacturers is indicated by the fact that this is the second edition. The first edition was only published in 1928, but the demand for this work has been such as to necessitate another edition.

In view of recent research work, the author has taken the opportunity to thoroughly revise the matter. The influence of impurities has occupied the attention of many investigators during the last two years, and the results of new investigations have become available since the first appearance of this book. The general arrangement remains unaltered; the first four chapters deal with the structure of pure metals and alloys, while in the remaining chapters consideration is given to the influence of minor impurities on structure, mechanical, and electrical properties, and on the corrosion of metals; the subject of each chapter, however, has been brought up to date by the inclusion of fresh data. The chapter dealing with influence of gas inclusions on the structure of metals has been enlarged, and the section on the influence of minor constituents on the mechanical properties of metals has been entirely rewritten and considerably increased. The mass of data dealing with the effect of metallic constituents on mechanical properties has been summarised at the end of the section, for greater convenience of reference. In its present form the book has an increased practical value. The comprehensive information is adequately indexed for reference purposes, and it will prove an acquisition to metal users and manufacturers, and, in addition, will indicate fruitful lines of investigation in the case of other metals and alloys.

By Colin J. Smithells, M.C., D.Sc. Published by Messrs. Chapman and Hall, 11, Henrietta Street, Covent Garden, London, W.C. 2. Price, 18s. net.

Transactions of the Institution of Engineers and Shipbuilders in Scotland, vol. Ixiii.

Part vii.

THIS issue of the transactions contains the discussion which arose as a result of the paper submitted by Kenneth M. Sloan on "Remedies for Some Engineering Workshop Inefficiencies." Mr. Sloan appreciated the fact that much of his subject matter was not new, but, even though information has been in existence for a long time, many engineering workshops are either without the information or unwilling to apply it. He considered this sufficient justification for supplying the information, and pleaded for its application.

The programme of the joint summer meeting, with the North-East Coast Institution of Engineers and Shipbuilders, held in Holland, is given in this issue, together with the papers submitted at this meeting. These include "The Interior Architecture of Ships," contributed by Prof. Percy A. Hillhouse, D.Sc., and A. McInnes Gardner, F.R.I.A.S., and "Notes on the Progress in Transportation of Oil by Sea and Possible Future Developments," contributed by John McGovern. Full discussions resulting from these papers are given. The issue also includes abstracts of two selected papers from the students' section, "Workshop Practice in Bridge Construction," by James Arrol, and "Centre and Chucking Lathes," by R. S. Anderson.

Institution of Mining and Metallurgy.

BULLETIN No. 312 contains two papers read before the third Empire Mining and Metallurgical Congress, held in South Africa. These have been reprinted by the Institution with the permission of the Executive Committee, and are submitted for discussion by correspondence, in anticipation of a discussion at a meeting during the ensuing session. These include "Water Concentration Tests," by Bernard W. Holman, and "Conservation of Drilling Records," by J. Allen Howe. As a result of a discussion on the latter paper at the concluding Technical Session of the Congress held at Durban, it was unanimously decided to refer the question to the Empire Council of Mining and Metallurgical Institutions, with the request that appropriate action may be taken with a view to making the conservation of drilling records compulsory.

Iron and Steel Institute

Autumn Meeting at Prague, Czechoslovakia.

THE annual autumn meeting of the Iron and Steel Institute, held at Prague, Czechoslovakia, September 15-20, proved to be a very successful meeting. The members were accorded a very hearty welcome by Dr. V. Sykora, on behalf of the Society of Czechoslovakian Engineers, who, in the course of a speech, expressed gratification that the invitation extended to the Iron and Steel Institute to come to Prague had been accepted. H.E. Dr. J. Matousek, Minister of Commerce, Industry, and Trade, in the name of the Czechoslovakian Government, welcomed the Institute, and the Lord Mayor of Prague, Dr. K. Baxa, on behalf of the Municipal Council of Prague, welcomed the members to the City. Dr. Baxa, in the course of a speech, commented on the close commercial and industrial relations established between Great Britain and Czechoslovakia, and said the visit would further increase the cordial relations already existing. A welcome was also extended by Dr. A. Sonnenschein, on behalf of the Czechoslovakian iron and steel industry, who, in the course of a speech, referred to the position of their works in the heart of Europe, and the distances some of their raw materials and export of finished materials had to be conveyed. Rationalisation to them was of great importance, as it was only by careful thought in organisation that prosperity could be assured. The President of the Institute, Professor H. Louis, in returning thanks to the various speakers for their cordial welcome, said it was the first time many of those present had visited Czechoslovakia, but the cordiality and kindness of their reception had been such as to make them feel at home. There was much in common with iron and steel makers throughout the world; they had similar problems, and although they might follow somewhat different paths, they all had the same object in view, and only by getting together and freely discussing difficulties could progress be made.

The Heterogeneity of an Ingot made by the Harmet Process.

A report on the heterogeneity of a nickel-chromium-molybdenum steel ingot made at the steel plant of the Skoda Works at Plzen by the Harmet method, was given in a paper by Dr. Ant. Kriz. The procedure adopted, he stated, followed as closely as possible the scheme outlined by the reports on the heterogeneity of steel ingots presented during recent years by a Committee of the Iron and Steel Institute.

The Harmet process is based upon the wire-drawing of steel during solidification in the ingot mould, and consists in the application of pressure to the fluid metal. The installation for this process, and with which the experiments were made for this report, is illustrated in Fig. 1. In this press the ingot mould is mounted on a solidly constructed bogie, through which passes the lower vertical ram. The bottom plate of the mould rests on the ram. In order that steel may be poured out of the ladle, the mould is moved out from under the press on the bogie. After casting an ingot, the mould is moved back and subjected to pressure.

During the compression, the bottom plate moves upwards in the cylindrical part of the mould, and forces the solidifying ingot into the tapered part of the mould. The top plate serves at the same time to exercise a counter-pressure, and to resist the formation of a "head." The side pressure that is exerted during the forcing of the ingot into the conical part performs the wire-drawing of the ingot. The compression, which may last from 4 to 7 hours, according to the size of the ingot being compressed and, when completed, the ingot is stripped by means of the upper plunger.

The casting temperature and the rate of teeming at the Skoda Works comply with the values normally used for the ordinary kinds of ingots. The compression is commenced from 15 to 60 mins. after the end of teeming. This period depends upon the size of the ingot, its casting temperature, and its rate of pouring. The larger the ingot, the higher the casting temperature, and the higher the rate of pouring, the longer is the period of waiting. The cooling of the mould by water is commenced as soon as the teeming is

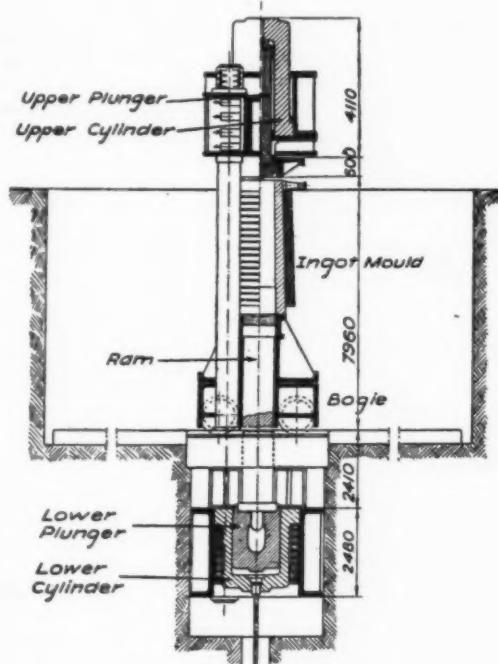


Fig. 1.—Harmet Process Installation.

finished, water being delivered at the upper portion of the mould and trickling down the hoops which encircle it. The mould for the ingot investigated is shown in Fig. 2.

Production Data of an Ingot Investigated.

The steel was made in an acid open-hearth furnace of 35 tons capacity, and the charge consisted of:—

9,100 kilogs.	Swedish pig.
26,130 ..	steel scrap with 1.5% of nickel.
345 ..	nickel.
340 ..	ferro-manganese.
85 ..	ferro-chromium.
120 ..	ferro-molybdenum.

The time from the melting down of the charge to its tapping was 7 hours. The procedure of the whole process was normal. The chemical composition of the cast was determined by the analysis of a bar forged from the middle portion of a small test ingot of a total weight of approximately 7 kilogs. The following was the analysis:—

	%		%
Carbon	0.31	Sulphur	0.022
Manganese	0.55	Nickel	2.09
Silicon	0.18	Chromium	0.41
Phosphorus	0.028	Molybdenum	0.26

For casting, a fireclay-lined tundish, 23.6 in. in diameter at the top, was employed. The depth of metal in the tundish was 27.6 in. The diameter of the nozzle was 1.38 in. The casting temperature at the end of teeming, measured by an optical pyrometer, was 1,375° C.

The period of casting lasted altogether 40 mins., the average pouring rate being 0.835 ton per min. The ingot weighed 33.409 kilogs.

The compression was commenced 35 mins. after the end of teeming. During that period of waiting the mould was cooled by water, 1,100 gals. being required. After that the compression was commenced, lasting in all 7 hours. The maximum final pressure was 8,000 lb. per sq. in. The total amount of cooling water used was 12,260 gals.

After being stripped, the ingot was placed in a previously heated annealing furnace, which was so fired that the temperature of the whole ingot would be uniform at 800° C. (1,480° F.). Finally, the ingot was left in the furnace to cool down slowly.

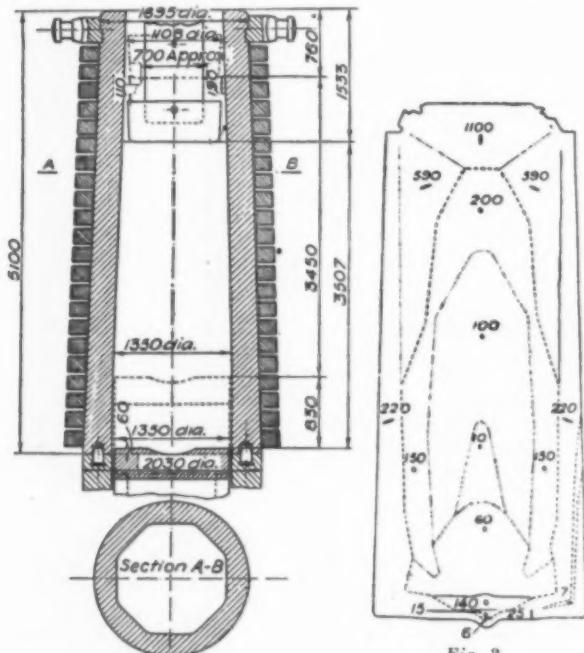


Fig. 2.—Ingot Mould.

Disposition of Crystals.

The ingot was subsequently cut along its longitudinal axis, and the middle lines of opposite faces. A sulphur print of the section was then taken. After being reground, the section was etched for primary crystallisation, and finally samples for chemical analysis in the form of drillings and of solid pieces were drilled out. The section showed the ingot to be quite free from pipe.

Primary Crystallisation.

The designation, "primary crystal," is given here with a certain reserve, as it is difficult at the present moment to say whether the crystalline structure revealed by etching is actually a primary crystal or whether it was preceded by a δ crystal.

The surface of the axial section was prepared by hand-scraping followed by grinding, emery-paper of medium fineness being used for the latter. After that the whole surface was etched by a method devised by Mr. J. Kocarek, who is in charge of the Skoda metallographic research laboratory. Three aqueous solutions were employed.

No. I.—Solution containing 12% of ammonium persulphate and 4% of concentrated hydrochloric acid.

No. II.—Solution containing 13% of chromic acid and 5.5% of concentrated sulphuric acid.

No. III.—Solution containing 4% of concentrated hydrochloric acid.

The etching was carried out in the following manner: First, solution No. I. was applied for 15 mins., then solution No. II. for 10 mins. After that, etching with No. III. for 4 mins., and finally again with solution No. II. for 7 mins., was performed.

This method of etching has the advantage that with it the "dislocated reflection" shows the greatest contrasts, and is limited to the areas of primary crystal grains only. The primary dendritic segregations are not revealed by that etching method. The etched section is more photogenic than when using other etching agents, as, for instance, ammonium persulphate solution or nitric and hydrochloric acids.

The boundaries between the columnar and granular crystals are shown in Fig. 3 by dashed lines. By "columnar crystals" are denoted those crystals in which one dimension considerably predominates. The "granular crystals" are those whose sections are more or less equiaxial polygons.

In the middle of the bottom, near the cooling plate, the thickness of the columnar zone is only 3.15 in. It increases towards the lateral faces of the ingot, so that in the outer half of the radius of the base it amounts to 5.90 in. The thickness of the columnar zone at the lateral sides of the ingot is about 7.09 in. This thickness of the columnar zone remains the same half way up the ingot. In the upper half of the ingot it increases towards the head from 11.8 in. to 14.2 in. At the bottom and the top the orientation of the crystals is perpendicular to the edge. At the walls of the mould the crystals are inclined upwards, forming with them an angle of from 77° to 66°. The angle decreases towards the head of the ingot.

The sulphur print taken not only gives a picture of the sulphur segregations, but shows in some zones the main axes of large dendrites, and these coincide with the main axes of columnar crystals, which is evidently in accordance with the direction of the temperature gradient. In the zone of large granular crystals, however, the main axes of the dendrites have such a varied orientation that no simple connection with the thermal gradient can be supposed.

Chemical Composition.

The axial section was drilled for samples for chemical analysis. Altogether 89 samples were analysed. The places from which the samples were taken formed a regular network. The border rows were 2.68 in. from the side edges, 3.54 in. from the bottom edge, and 5.91 in. from the top edge. In each horizontal row seven samples were taken at equal distances from each other. The distance between the horizontal rows was 10.8 in. The lowest row was curved towards the bottom, the uppermost one towards the top, all the others being straight lines. With regard to the taper of the ingot, the distance between the positions of samples in the lowest horizontal row was 7.87 in., while in the top row it was 6.77 in.

TABLE I.

Element.	Average Value, %.	Lowest Value, %.	Highest Value, %.
Carbon	0.30	0.27	0.43
Manganese	0.55	0.53	0.58
Silicon	0.17	0.16	0.20
Phosphorus	0.031	0.026	0.058
Sulphur	0.019	0.017	0.037
Nickel	2.07	2.03	2.09
Chromium	0.40	0.39	0.43
Molybdenum	0.25	0.23	0.27

In Table I. the lowest and the highest values for each element found by analysis are given. The average values given in the table have been calculated on the basis of the arithmetical averages of all the values found. Those average values were then taken as a basis for calculating the total percentage differences within which the analytical

values of each element varied, the greatest negative and the greatest positive percentage differences being estimated as well. The arithmetical averages were taken as the basis for the percentage calculations instead of the "melt" analyses, because an arithmetical average of 89 samples guarantees better the average values of the analyses.

Differences from the average value expressed as percentages are shown in Table II.

TABLE II.

Element.	Average Value, %	Percentage Difference from the Average Value.		Total, %
		Negative, %	Positive, %	
Carbon	0.30	10	33	43
Manganese	0.55	4	5	9
Silicon	0.17	6	18	24
Phosphorus	0.031	16	87	103
Sulphur	0.010	10	95	105
Nickel	2.07	2	1	3
Chromium	0.40	2.5	7.5	10
Molybdenum	0.25	8	8	16

With regard to the distribution of individual elements which show strong segregation, a minimum of phosphorus and sulphur is to be seen at the axis of the ingot. The position of these minimum segregations, however, appears nearer the bottom of the ingot than it does in the case of ingots cast in the usual manner. A clear maximum of carbon, phosphorus, and sulphur is found at the positions of the characteristic sulphur segregation under the head.

Discussion.

The discussion was opened by Dr. W. H. Hatfield, who referred to the first report of the Heterogeneity Committee, presented to the Institute, and stated that there had been no opportunity of studying an ingot made by the Harmet process. Dr. Kriz had now, however, stepped into the breach and given the Institute the desired information. Continuing, Dr. Hatfield suggested that those who had raised the question as to whether the application of pressure during solidification diminished the heterogeneity of the resulting ingot, would find the answer in the sulphur print which was displayed. They would see that, in spite of the pressure, the process of differential freezing had not in any sense been modified, and heterogeneity was disclosed in all its features, as found in an ingot in which pressure had not been applied. There had, however, been a certain amount of displacement of the structure on account of the work put into the ingot during the process.

There was an increasing need for large ingots, he said, and ingots weighing from 100 tons to as much as 150 tons were now required. At the Sheffield works of Messrs. John Brown and Co. a 6,000-ton press was installed about the year 1906, but its use was limited to a 30-ton ingot. He suggested that probably the maximum ingot which the Skoda press could accommodate was a 40-ton one. This meant that these presses could not be used for the large ingots now demanded. The author's illustrations indicated that the Harmet press demanded an ingot having the smaller end at the top and the larger at the bottom. In the light of modern knowledge this was a bad feature; the smaller end should be at the bottom. Commenting on the delay in applying the pressure, Dr. Hatfield said that pressure was only applied after an outer crust, 7 in. thick, had been formed. In England, on the other hand, pressure had always been applied as soon as the ingot was cast.

Professor R. Vondracek, after referring to many valuable reports on important subjects which were kept in the records of the Skoda Works, said it was gratifying that this paper marked a change in that practice. He suggested that most of the results of the investigation were in accordance

with those of the two reports on the heterogeneity of steel ingots, presented to the Institute. It was once again confirmed that the binary alloys, in which the liquids and solidus lines were close together, did not tend to cause an increase in the degree of segregation.

Professor Bradley Stoughton, joining in the discussion, stated that the compression process had been used in past years in the United States. The last remaining Harmet press, however, had been dismantled a year or two previously on account of the length of time required and the cost of the compression operation. He was inclined to think that perhaps they had been too hasty in abandoning the method.

An interesting experience was referred to by Mr. C. H. Ridsdale, who stated that in 1925 he wished to obtain a bloom for the purpose of making analytical standards. He obtained a bloom from a Harmet-pressed ingot. This was of carbon steel, containing 0.13% of carbon, 0.527% manganese, and 0.176% of silicon. Although this piece was not an ingot, it was representative of the whole cross-section of an ingot. The bloom was cut and the analysis made at six depths from the outside to the core. These revealed that the variations in the steel were lower than the experimental error of the chemist. He was not aware of the size of the ingot, but judged that it would not be less than 12 tons in weight.

Dr. A. McCance suggested that the main result of the Harmet process, as shown by the sulphur print, was the absence of A—segregates down the centre of the ingot. Mr. W. Austin referred to the method adopted in taking the arithmetic average of a large number of analyses for the results as a notable step.

Reasons for the Introduction of Thin-Walled Blast Furnaces.

The paper on this subject was introduced by Mr. E. Czeike-Zentzytzki, on behalf of the author, Dr. Jundrich Sarek, and referred more particularly to the reasons why the Prague Ironworks Co. has introduced thin-walled blast-furnaces. Four years ago this company decided to install furnaces of this type, and now that the fifth is being built the experiences, as described by the author, are of special interest. In addition, he outlines a new theory of furnace working he developed a few years ago, which distinguishes two different modes of blast-furnace working—"internal" and "external." In actual practice fully developed "internal" or "external" modes of running are not met with, but different modifications or combinations of both occur.

The author discussed the advantages of thin-walled furnace as illustrated in Fig. 1, and, from the theory of the blast-furnace working which he outlined, gave a review of the difficulties which are encountered by works producing "cold" grades of pig from lean and acid ores, these difficulties originating from a low permeability of the stock in the lower portions of the furnace. The blast furnaces continually exhibit hanging, sticking, and scaffolding, resulting in interruptions of operation and an increase of coke consumption, may be ascribed to the effect of this low permeability; hence, the only thing to be done is to adjust the operating factors so that the furnaces have a slight inclination towards the "external" mode of running, which is not difficult to perform on the basis of the new theory he discussed. This theory becomes consequently a valuable guide in operating blast furnaces, which gives information on the mode of furnace working and so prevents many an interruption in their operation. This theory explains at the same time why on installing big blowers some furnaces have changed their mode of running; those were furnaces in which some chance gave rise to a tendency towards "external" running. Since, however, in practice the furnace working shows continual fluctuations, such furnaces work within limits defined by regular working on the one side and a sufficiently pronounced "external" mode of

running on the other. Such a state of working requires constant careful attention to the furnace, it being then possible to prevent an increase of coke consumption; the destruction of the furnace lining, however, cannot be prevented. Non-uniformity of the stock and other changed conditions continually and repeatedly cause some portions at the periphery of the furnace to run more "externally" than is necessary, the result being the destruction of the furnace lining, mainly at the belly and at the bottom of the shaft. Since these irregularities take place alternatingly at various places at the periphery, it is not long before the furnace lining in the lower portions of the shaft is irregularly melted off to a "skin" only a few centimetres thick, which then holds out relatively well. The furnace, of course, changes its lines entirely, and the possibility of very irregular working, scaffolding, and melting off at new places is given full play; in short, such a furnace, abnormally and irregularly widened in the lower part of the shaft, with the bosh considerably enlarged, due to the melting off of the lining, and with the belly considerably increased in diameter and raised above its normal position, can be operated with great difficulty only, and becomes a unit consuming an unnecessarily great amount of coke, which cannot work economically. It is consequently worth while to rebuild such furnaces after but a few years' run; the only profit is the decrease of the difficulties and interruptions in operation, there being no saving in expense, since the saving in fuel consumption is balanced by the cost of rebuilding.

Operation Difficulties.

The difficulties of operation mentioned manifested themselves strongly at Králov Dvur, where the furnaces designed for smelting Thomas pig from native ores are frequently required to produce "hot" grades of pig in short campaigns from rich burdens with foreign ores, and the furnaces, with lines designed for "hot" grades of pig must often be used for smelting Thomas pig. With the design and operating factors adjusted for the production of Thomas pig, the furnace suffered immensely when producing "hot" pig, its run being normally a rather well-developed "external" one, especially when it was not worth while to change all the operating conditions for the short duration of the campaign. Similarly, the furnace designed for "hot" grades of pig when employed for the production of "cold" pig, had to be artificially brought to a condition inclining towards "external" running, and then became damaged. The result was that the blast-furnace walls were melted off and irregular deposits were formed on them within a short period of time, the furnace offering thus no more ready means of control and becoming costly in operation.

Observations made at Kladno and at Králov Dvur, that the furnace lining, only a few centimetres thick, which was the case at the places where it was melted off, would last well for a comparatively long time, led to the consideration of means of utilising this fact. Since the thick lining melted off at the inner surface because it was not sufficiently cooled, whereas the thin lining cooled by air proved to be successful, it was easy to conceive the idea of building thin-walled furnaces. The chief argument against this idea, which was supported by the literature on Burgers' furnaces, was the fear of an increased fuel consumption. Since, however, furnaces with melted-off linings and irregular deposits on the walls, being uncontrollable, worked on a higher coke consumption than sound furnaces maintaining their original lines, which could not last long, and since, besides, there were many failures in operation, it was expected that the introduction of thin-walled furnaces might lead even to some lowering of the coke consumption in comparison with that in furnaces of the old type, and certainly would result in a decrease of failures in operation. And the not very satisfactory experiences of older days with cooling plates, which were then installed in the furnace bosh, led to the introduction of armoured water-cooled thin-walled furnaces. The first was installed four years ago at Kladno, and now the Prague Ironworks Co. is already

building its fifth furnace of this type (Fig. 1). Experience gained during these four years has fully justified the expectations. The furnaces preserve practically constantly their original lines, the lining does not melt away for long periods of time, troubles in operation are decreased, and the consumption of coke is not increased, but is even lowered.

The linings of two of such furnaces were examined, one at Kladno after two years of operation, and the other at Králov Dvur, where the furnace was blown out after eighteen months of operation, and in the discharged furnace it was detected by boring that the lining was worn uniformly, less in the middle part of the shaft, and more in the belly. The original thickness of the lining of the latter furnace was 250 mm., and after eighteen months of operation the lining was 180 mm. to 200 mm. thick in the middle of the shaft, and 120 mm. to 140 mm. in the belly. Now, when equilibrium between the heating and cooling has been reached, this thickness will probably stand for a very long period, undergoing only mechanical wear.

The consumption of coke during the last four years of operation at Kladno and at Králov Dvur was compared with that of former days on the basis of diagrams plotted

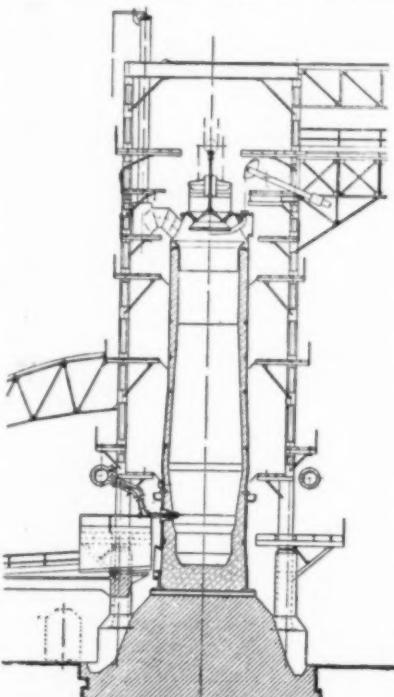


Fig. 1.—Thin-walled Blast Furnace.

from data obtained with charges of various richness, consisting of similar ores, and otherwise smelted under the same conditions, and it was observed that the average coke consumption was lower in thin-walled furnaces than in furnaces of the older type.

Due to the fact that the lines of the thin-walled furnaces remain practically unchanged for long periods, the furnaces are always under control, and therefore failures in their operation occur less frequently, and the operation itself is

rendered less difficult. Of course, thin walls do not prevent the possibility of the building up of deposits; these deposits, however, do not occur so readily, and may be comparatively easily removed owing to the ease of control of the furnace. The only disadvantage of these water-cooled furnaces which may be mentioned is an increased consumption of cooling water. Their construction itself is not more expensive than that of the furnaces of the older type; the lining being only 150 mm. to 250 mm. thick, the saving on the cost of the fireclay bricks is equal to the extra cost of armoring the furnace. Moreover, when it is appreciated that the erection of a heavy supporting structure is not required for new furnaces, the great advantages which the Prague Ironworks Co. derives from these thin-walled furnaces become even more obvious.

Discussion.

The discussion on this paper was opened by Mr. A. Hutchinson, who said that he would have welcomed the dimensions of the furnace and more data on its actual working and operation. Mr. W. Simons referred to the

usual practice in Great Britain in using steel-cased linings, but there was apparently a wide range of practice in regard to the construction of blast furnaces. He expressed a wish to know the tonnage of pig iron produced during the life of a lining in this type of blast furnace, as, in his opinion, 750,000 tons of pig iron should represent the production of pig iron during the lifetime of a lining; this was an important economical factor. Professor R. Vondracek said that the author had dealt mainly with difficulties arising from the improper penetration of the charge column by the blast. The reasons for this irregularity had been the subject of a large number of investigations. Mr. J. E. Johnson, in his work, *The Principles, Operation and Products of the Blast Furnace*, stated that if the gas stream were too much in the centre of the furnace, and a scaffold begun to be built on the walls just above the tuyeres, this would tend to throw the gas still more strongly to the centre, and thereby favour still further building up of the walls, this condition continuing until the furnace could no longer operate. On the other hand, when penetration was deficient, a cone was built up in the centre of the hearth and filled the latter up until there was nothing left for the passage of the gases, but a narrow ring around the outside. In this case the tendency was for the blast to be thrown back more strongly against the walls, and so cut them away more actively. The information that the coke consumption in thin-walled furnaces was even lower than in those of the older type was interesting, and it would be helpful to know what the reason of this reduced fuel consumption might be, particularly if data on the present and the previous coke consumption could be given.

Mr. David E. Roberts stated that the most suitable method of dealing with the lining above the lintel had engaged the attention of blast-furnace men for many years. He referred to the drawing of the furnace given in the paper, showing that the thin lining was brought right down to the hearth. Although he was in full sympathy with thinning down that portion of the lining which stood above the lintel, it would take a great deal to convince him that a thin-jacketed lining gave the best results below the lintel. Professor Bradley Stoughton, who joined in the discussion, said that some time previously there had been quite a vogue in the United States for thin-walled blast furnaces, but after a few years the interest had died down. He could not give a reason for this, except, perhaps, that blast-furnace problems in the United States were connected more with the utilisation of the soft, fine Mesaba ores. No doubt the various difficulties connected with the treatment of these ores, which had arisen, had caused the question of the utilisation of thin-walled furnaces to be forgotten.

Mr. E. Czeike-Zentzytzki, in a brief reply to Mr. Simons' question on outputs, said that their furnaces at Kladno were producing, per week, from 2,100 to 2,500 tons of basic Bessemer pig iron of good quality, low in sulphur and in silicon. The furnaces at Králov Dvůr were smaller; they produced from 1,200 to 1,210 tons of foundry and forge pig iron per week. As regards the tonnage of output equivalent to the life of the lining, the first furnace had been installed four years previously, and had been in regular operation ever since, producing about 2,100 tons a week. The idea of building these furnaces had come gradually. They had first carried out water-cooling up to the bosh. This process had been continued farther and farther, until now they water-cooled the furnace right up to the top.

Permanence of Dimensions Under Stress at Elevated Temperatures.

The last paper during the first technical session was submitted by Dr. W. H. Hatfield, in which he stated that one of the most difficult problems before the metallurgical world at the moment was that of determining fundamental data for the use of the designer which would enable him to be certain that the stresses with which he has to deal at elevated temperatures could be carried without deformation.

The question was frequently asked can there be permanence of dimensions at normal temperatures? As a result of many investigations, it is asserted that there is no absolute permanence; but engineering experience over long periods of time has shown that for all practical purposes permanence of dimensions under heavy stress is undoubtedly attained within measurable accuracy over very long periods of time. It is theoretically necessary to endeavour to establish the fact one way or the other by experiment.

One such experiment is still continuing in the Brown-Firth Research Laboratories, and is described in this paper, since the results are of sufficient interest in their bearing upon the problem. It consists of stressing, at 25 tons per sq. in., a strip of cold-rolled rustless austenitic chromium-nickel steel (limit of proportionality, 27.4 tons per sq. in.; 0.1% proof stress, 60.7 tons per sq. in.), the extensometer being constructed also of rustless steel. The selection of rustless materials removes a danger of corrosion during the life of the experiment. From June 1, 1929, to June 12, 1930, there has been no movement within an accuracy of measurement of one forty-thousandth of an inch; the length between gauge points of the specimen is 8 in. A simple calculation, therefore, will disclose that if movement is taking place under this very considerable stress, it is, at any rate, of a less order than one two-thousand-eight-hundred-millionth of an inch per inch per hour. The nature of this experiment indicates the extreme difficulty of dealing with the whole question of stability of dimensions.

The author has been content simply to present the data obtained in the experiments. Having carefully stated his point of view and the conditions of the manner in which the time-yield is obtained, he prefers that those who are interested shall evaluate the results. In the light of information to date, the author is prepared to advise the designing engineer to accept a figure of two-thirds of the time-yield as his safe stress in tension.

Effects of Corrosion.

The effects of corrosion resulting from the influence of elevated temperatures upon the steel are referred to in this paper. The author stated that everything depends upon the nature of the atmosphere to which the steel is subjected, and each case must necessarily be considered upon its merits. Researches in this field have been in hand for some considerable time in the Brown-Firth Research Laboratories, and it is hoped to publish some of the results at an early date. In the meantime, reference may be made to one particular case—namely, the effect of steam upon mild carbon steel at high temperatures and pressures. Experiments to date appear to indicate that a layer of oxide is initially formed, which, judged over a short period of time, would indicate a definite scaling factor too considerable to be ignored, but cumulative evidence tends to show that the characteristics of this scale are of such a nature as to protect the steel from progressive attack. It thus appears probable that more complete investigation will show that danger from excessive scaling within the ranges of temperature at present under consideration—up to 1,000° F. (538° C.)—is not likely to be anything like as serious as was at first anticipated. It should, however, be borne in mind that if the scale functions in this suggested protective manner, it is essential that local damage, from any cause, be prevented.

Dr. Hatfield, in presenting his paper, said that when considering the behaviour of steels at elevated temperatures, the influence of time became of great importance, particularly at temperatures in excess of 300° C. Considerable time was required to obtain a satisfactory value of limiting creep stress at one temperature. The method employed in the present investigation consisted in discovering, by static loading, the stress within which, at the given temperature, stability of dimensions was attained within a period of twenty-four hours; for a further period

of forty-eight hours, with an extension not exceeding the elastic deformation of 0.5% on the gauge length, and with limitation as regards measurement for permanence of dimensions, of the order of one-millionth of an inch per inch per hour. This value he had named the "time yield." A single test for a given temperature could be obtained in three days, and the time-yield values for carbon, ordinary alloy steels, rust-resisting and heat-resisting steels, die and high-speed steels, at 400°, 500°, 550°, 600°, and in a few cases at 700° C., had been determined. Mr. F. W. Harbord, in opening the discussion, said one of the engineer's most important duties was to say what the limit of safety was. He was unable to do this, and Dr. Hatfield had, in his paper, given a reasonable approximation of what was a reasonable limit, which was at least a start towards the solution of a difficult problem.

Dr. A. McCance was of the opinion that the author had not distinguished between total deformation and rate of deformation. The very basis of his test was the examination of material with a very slow rate of deformation. The question of a quick test was of great interest, as ordinary tests took a great deal of time. Bailey had now postulated that a rate of deformation of one thousand millionths of an inch was necessary to secure an accurate conception of creep. The behaviour of some of the steels tested was extraordinary, and might lead to the diminishing of the number previously suggested for high temperature resistance purposes, which he hoped would result.

Dr. Hatfield, in reply, agreed that the curve put forward was tentative. Fresh data were constantly accumulating, and with methods less exact the results used to be higher than they now were, but the accumulation of fresh data could not be postponed pending the refinements necessary to secure highly accurate results. Those described in the paper were sensitive to 1/3,000 millionth of an inch, and the results took over a year to obtain. It was a question of choosing between the time factor and the sensibility of measurement. Dr. McCance was quite right in his suggestion that not all the steels put forward as heat-resisting possessed all the advantages claimed for them. It was possible to have 30 to 40% of chromium present without increasing the heat-resistant strength, or to put in a lot of nickel, and not do so. Together they increased the strength a little, but did not give the requisite strength at high temperatures. If, however, tungsten were added, a material was obtained possessing strength at elevated temperatures. As a matter of fact, the chromium-nickel-tungsten steels came out very well and gave reliable high-temperature resistant qualities.

Analysis of Basic Slags.

The first paper in the second technical session was presented by Professor Otakar Quadrat, and was entitled "A Contribution to the Problem of the Analysis of Basic Slags and the Representation of their Composition in a Triangular Diagram." In the paper, which was read in abstract by Professor J. Heyroovsky, the author pointed out that little attention is paid in literature to an error involved in the determination of ferric oxide and sulphidic sulphur in basic open-hearth slags. The determination of sulphidic sulphur by decomposition of the slag by acid in a current of carbon dioxide, following the usual procedure adopted with an apparatus as used for the determination of sulphur in iron, absorption of the sulphuretted hydrogen in cadmium acetate, iodometric determination of the sulphur, and oxidimetric determination of the bivalent iron, produces results for the sulphur which are too low, while those for the bivalent iron are too high. The content of the trivalent iron, as represented by the difference between the total iron and the bivalent iron, is then lower than the amount actually present. The error is due to reaction, which takes place when the slag is decomposed by acid, as well as to a reaction between the sulphuretted hydrogen liberated and the ferric salt. He worked out a procedure for the accurate determination of ferric oxide and sulphidic sulphur.

In the first place the total sulphur and the sulphate sulphur were determined gravimetrically: the difference between these two figures indicates the content of sulphidic sulphur *a*. Then the sulphidic sulphur *b* is determined iodometrically, by the method mentioned above, in a separate sample of slag, and the bivalent iron contained in the solution of decomposed slag is determined oxidimetrically. For decomposing the slag, a mixture of dilute sulphuric acid and hydrochloric acid is used. The difference, *a*—*b*, indicates the amount of sulphidic sulphur *c* which is lost in the iodometric determination. This amount *c* is equivalent to that of the trivalent iron which is reduced when the slag is decomposed. By subtracting this figure from that for the bivalent iron, as determined by titration, the accurate figure for the bivalent iron is obtained. For the rapid determination of sulphidic sulphur in slag, the trivalent iron is reduced by zinc powder at an elevated temperature, and the sulphidic sulphur is determined iodometrically in the product of this reaction.

The results of the complete analysis of 25 slags were plotted in triangular diagram, in which the components considered were bases, oxides, and acids.

Attention was drawn to the existence of a ferric-oxide metallic-sulphides labile system, the existence of which he explained by the presence of calcium ferrite, which has a lower oxidising effect than would be exhibited by ferric oxide acting as a base.

Discussion.

The Secretary read a communication from Dr. J. Sarek, in which he stated that Professor Quadrat had given a triangular representation of open-hearth slags similar to that plotted by Boudouard and Mathesius for blast-furnace slags. The gypsum model of Mathesius, however, had found but little application, as it did not characterise great changes of properties, especially in regard to the fusibility, brought about by relatively small changes in composition. For example, a slag containing 2.5% of sulphur was normally liquid; on the other hand, a slag containing from 3 to 3.5% of sulphur did not flow. He further stated that the content of barium sulphide influenced the fluidity of blast-furnace slags, and such great changes in fluidity could not be represented by the Mathesius diagram, as now known.

Professor R. Vondracek considered the procedure for the accurate determination of ferric oxide, indicated in the paper, was of particular value, as it would make it possible to arrive at more reliable conclusions on the function of the ferric oxide in open-hearth slags. The idea of plotting the composition of the slags in a triangular diagram, similar to that of Mathesius for blast-furnace slags, was attractive, but was difficult. It might be worth while to attempt other methods of representing basic slags diagrammatically, but it was doubtful whether both the oxidising and the melting properties could be expressed in one diagram.

Professor A. Mitinsky, joining in the discussion, said it did not seem possible to him that any triangular diagram could furnish data applicable to slags of different furnaces. A slag being formed of many components—chemical combinations and solid solutions—small differences in chemical composition might cause the formation of new phases which influenced the properties of the slag. If the new phase produced were of solid particles, the transparency and fluidity of the slag might be completely changed. Difficulties in the application of a triangular diagram were evident. The study of the systems present in open-hearth finishing slags, however, was only just beginning.

Mr. T. P. Colclough stated that the effect of the sulphur present in the slag, in giving a false determination of the iron, had given trouble for a considerable number of years. He agreed that the representation of the composition of a basic slag in the form of a triangular diagram was, to say the least, controversial.

Professor H. Louis assumed from the discussion that the combination of oxide of iron with lime had been accepted as something new, but his old teacher, Dr. Percy, had melted together ferric oxide and lime and had obtained a deep-red crystalline compound which had been exhibited at the Geological Museum in Jermyn Street upwards of fifty-five years previously. In England we were apt to "bury" original work, and the facts were sometimes subsequently rediscovered abroad and put forward as new data.

High-Frequency Steel Furnaces.

Further papers included one on "High-frequency Steel Furnaces," which was submitted by D. F. Campbell, in which he stated that there is no justification for supposing that the induction furnace is limited to the simple metallurgical operation of melting small quantities of high-class raw materials to produce tool steel.

A survey of the present status of the ironless induction furnace will show that its field of utility is much wider than

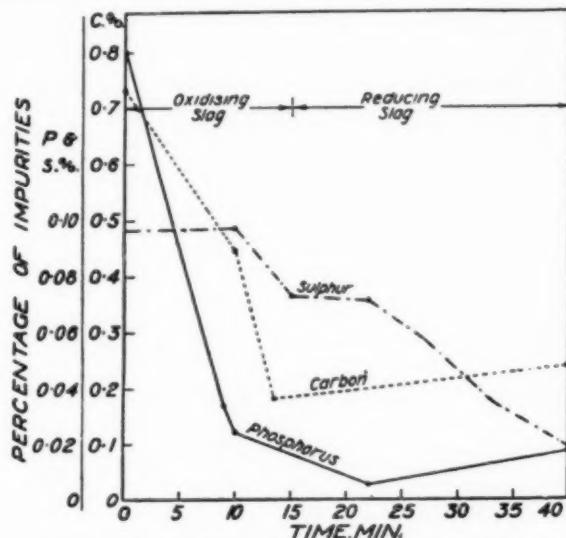


Fig. 1.—Time and Percentage of Removal of Impurities.

is generally supposed. It is supplementing certain processes, replacing various types of furnace in part, and though its limitations of size will prevent its application to certain operations requiring large ingots or castings, the rapidity of operation will have an important bearing on steelworks practice outside the melting shop.

At present the largest units are furnaces of 20 to 25 cwt. capacity per heat, giving an output of 20 tons per day, but the design of furnaces of 3 to 5 tons presents no technical difficulties, as many details of construction are easier in furnaces of large dimensions, while large motor-generator sets can be built to operate at lower speeds, and their design is well within established practice. There appears to be no technical reason to prevent the construction of units of any size that is commercially practicable, though economic considerations indicate the probability that units of less than 15 to 25 tons will be adopted, as in the case of steel-making by the Bessemer or Thomas processes.

At present the steel-making operations to which these furnaces have been applied are as follows:—

- The melting of high-class tool steels in acid-lined furnaces to replace the crucible process.
- The melting of low-carbon steel and alloys.
- The melting in an acid lining of rolling-mill scrap produced from steel made in basic-lined arc-furnaces.
- The melting of heat-resisting steel and refractory chromium alloys.

(e) The melting of nickel-chromium alloys.

(f) The remelting of manganese scrap.

(g) The melting of hard materials, such as tungsten carbide.

In addition to these established industrial uses, rapid progress is being made in determining the commercial value of the metallurgical operations involving the refining of steel which is performed in basic-lined furnaces by slag reactions similar to those used in arc-furnaces.

The refining operation is extremely rapid, owing to the circulation of the metal due to electrical forces. Furthermore, this movement constantly brings hot metal in contact with the underside of the slag layer, thus keeping it hot and maintaining ideal refining conditions at the slag-metal contact surface.

Figs. 1 and 2 show the extraordinary rapidity with which carbon and phosphorus are removed under oxidising conditions. These may be obtained either by the use of iron oxide in the form of ore or mill-scale, or, alternatively, by an air blast. Sulphur may also be removed more slowly, and the usual slag reactions may be worked with great rapidity, owing to the speed with which fresh metal is constantly brought into contact with the refining slag.

The progress in duplex processes—either with the open-hearth or with electric arc-furnaces in countries where the latter is the cheaper melting unit, where steel must be finished in an acid lining and only basic steel is available—show considerable promise.

The conversion of molten pig iron into steel with the elimination of carbon, silicon, manganese, phosphorus, and sulphur, is carried out in basic-lined furnaces. The possibilities of converting liquid pig iron into steel are extremely interesting on account of the great rapidity with which the reactions occur owing to the intense circulation. The excessive over-oxidation of the basic Bessemer (Thomas) process is avoided, and by control of the circulation the conditions may be varied from those of a violently oxidising furnace to the comparative tranquility of an open-hearth or crucible furnace, which is desirable for finishing processes.

If a comparison be made between a steelworks equipped with six 75-ton open-hearth furnaces producing 6,000 tons

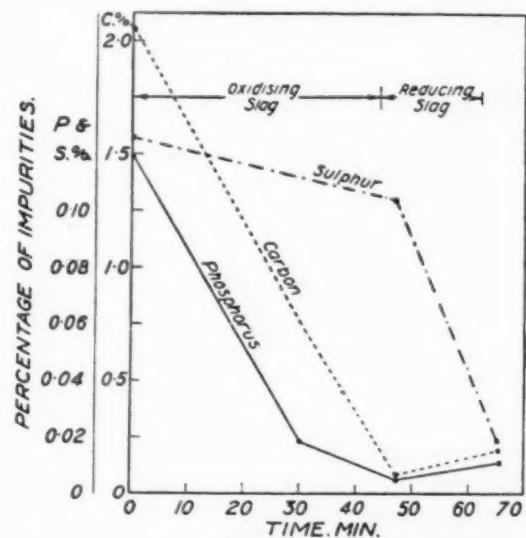


Fig. 2.—Steel Refining in the High-frequency Furnace.

a week, and ten 6-ton high-frequency units giving the same output and casting direct into ingot moulds, it will be found that the capital cost of the latter equipment will be considerably less, and the operating advantages would be numerous. Instead of 100-ton cranes and buildings of corresponding strength, the maximum lift in the melting-

shop would be limited to 10 tons, while a regular supply of ingots would be available at regular intervals, which would avoid the necessity of large and expensive soaking pits and ladles. The fact that steel may be charged within a few minutes of starting work on Monday morning, and the possibility of completely shutting down furnaces during week-ends, are important features which are also attractive in the case of the Bessemer process.

The space occupied by six 75-ton open-hearth furnaces, and ten 6-ton high-frequency furnaces, with two metal mixers in each case, would be about 70,000 and 32,000 sq. ft. respectively.

The present state of development justifies the statement that such refining furnaces can now be made. Details of metallurgical practice doubtless require further experience, and the difficulty of sample-passing requires consideration, but the accuracy of heat control in electric furnaces, and the absence of combustion gases, should give such uniformity of product as to reduce the necessity for sample-passing.

The author gave the following figures to show the results obtained when melting alloy steels of the composition indicated in 10 cwt. and 20-25 cwt. furnaces respectively.

The higher power consumption of the larger furnaces is not always due to a difference of efficiency in the melting equipment, as steel-making practice varies very much in different works. There is a great variety of opinion about the importance of this time factor in steel-making.

10 CWT. HIGH-FREQUENCY FURNACE. 20 CONSECUTIVE HEATS.

Heat	Type of Steel.	Time, Min.	Kw.-hr. per Ton.
4	18% tungsten	63	640
5	18% "	65	650
6	Carbon	64	640
7	"	66	700
8	20% tungsten	54	576
9	20%	54	588
10	20%	53	553
11	Carbon	62	652
12	"	66	658
13	"	60	635
14	18% tungsten	59	610
15	20%	65	600
16	20%	60	634
17	Stainless	69	686
18	18% tungsten	57	608
19	18% Cr, 8% Ni	59	626
20	20% tungsten	85	670
21	20% "	54	572
22	20%	61	590
23	20%	57	582
24	20%	53	578
25	20%	50	556
26	20%	54	572
27	20%	55	556
28	20%	54	548
29	20%	55	554
30	20%	53	579
31	20%	56	579

Average per charge : 60 mins.; 605 kw.-hr. per ton.

RESULT OF MELTING HIGH-GRADE ALLOY STEELS IN A 20/25-CWT. AJAX-NORTHRUP FURNACE. (5 CONSECUTIVE HEATS).

Type of Steel.	Time, Min.	Weight of Charge, Kilogs.	Kw.-hr. per Ton.
2% nickel	82	1,250	670
Carbon-chromium	87	1,050	710*
Manganese	75	1,050	590
Manganese	65	1,050	590
Nickel-chromium	87	1,250	525

* First heat of day; cold furnace.

With the above furnace 30 consecutive heats produced 34,300 kilogs. of ingots for a power consumption of 690 k.w.-hour per 1,000 kilogs., including all delays, stoppages, and time occupied in casting.

This method of steel-making is full of promise of further development, as the author claims it is cheaper to operate than the arc-furnace, and involves less capital expenditure than open-hearth furnaces of the same daily output.

Discussion.

Dr. Ing. Bernhard Matuschka, in opening the discussion, said Mr. Campbell had mentioned the growing importance of the ironless induction furnace. With the cost of power reasonable, the high-frequency furnace was undoubtedly advantageous where high-quality steel was desired. It worked more cheaply than the small types of arc furnaces. Experience, he stated, showed that working with the larger types of these furnaces was not more, but, in fact, less, difficult. The induction furnace, Dr. W. H. Hatfield agreed, was essentially one for special steels rather than for heavy production, but he wanted a little more assurance that complete control was possible. Rapidity of production was an advantage, but it made quantitative control difficult. He desired information on the method of controlling the casting temperature.

The question of testing the steel before tapping presented a difficulty to Mr. J. Henderson, who said that a 6-ton ingot was not large enough for some operations. The cost of power was a most serious point, at only a farthing per unit it amounted to a very high figure compared with Siemens practice. Dr. A. McCance said that a high-frequency furnace owned by his firm was working very well; the methods of control were simple. They had not had sufficient experience as yet in regard to the quality of the steel produced, but it was at least as good as the best acid open-hearth products.

Professor Bradley Stoughton expressed the opinion that, as a result of his experience, the very highest quality was obtained from the Ajax-Northrup furnace. Temperature control was very easy. A better determination of temperature is possible than from an arc furnace, and it seemed to him that the high-frequency furnace, used as a re-melter without any black slag whatever, should give a quality equal to the very best.

Mr. F. W. Harbord said that, as a result of a few experiments, he had obtained great control over the temperature. He thought European experience had shown that this furnace was, for high-quality steels, a great advance on the arc furnace, and had all the advantages of the crucible process and some of its own. Professor Bradley Stoughton, in further discussing the subject, expressed his conviction that if crucible quality was to be approached in the electric furnace, no phosphorus or carbon should be oxidised in that furnace. A lime slag should be used at the start.

In his reply, Mr. Campbell considered the references made concerning the arc and high-frequency furnaces. His view regarding the oxidising slag in the arc furnace was that, with alloy steels, if the dephosphorising and oxidation were done at the right temperature, success resulted; a plain carbon steel was more difficult to make. Great success had been attained in making almost every kind of steel in that furnace except carbon steel very low in manganese and silicon, but that difficulty was being overcome. Casting temperatures were, he thought, under control. It was easy to move the slag aside and use the ordinary pyrometric methods. Another way was to use the kilowatt meter, which gave very accurate control. The inspection and sampling of steel was a serious difficulty with small units, but in time that would be overcome, because with the high-frequency furnace there was much less variation and, therefore, less need of constant sampling. He considered there was better control of oxidation than with any other process.

Recent Developments in Tools and Equipment

New Type of Heavy Duty Milling Cutter

WHILE the development of special cutting materials has been making rapid strides to cope with greater speed in production, and with advances made in the use of high-duty metals and alloys, the tool designer has been investigating and carrying out experimental work with a view to making effective use of these special cutting materials. It has been recognised for some time that the conventional type of milling cutter manufactured in the super-cutting alloys now available is both extravagant and inefficient, as only a small proportion of the material could be actively utilised. The desirability of taking full advantage of the progress in cutting alloys is responsible for a recent development in milling cutters of composite type, as represented by the Brooke "Cardinal" cutter.

This type of milling cutter comprises a tough forged body of medium tensile steel, admirably suited to its sole duty of transmitting power and withstanding shock. Into the periphery of this body blades of high-duty cutting alloy are introduced. These blades register on the body sides as shown in Fig. 1, and are homogeneously amalgamated, with the cutter body by fusion, the finished cutter being virtually a solid cutter, and ringing, when struck, exactly as does a solid cutter.

The wide variety of these milling cutters are now manufactured in two bladings. In one series the cutting elements are of the highest grade 18% tungsten alloy. These are eminently suited to all classes of work and conform closely in cost to ordinary solid cutters, to prove superior in service.

In the second series advantage is taken of the unique possibilities of the latest tungsten-cobalt-chromium alloys. Cutters equipped with cutting elements of this material function admirably. This latter series is recommended for the highest performance in difficult materials.

Experiments have shown that this type of cutter was capable of withstanding a duty that rapidly broke down the cutting edges of a solid cutter made from the same steel as that used in the blades, and of identical physical condition. Investigation appeared to show that the effect was due to the absorption of tooth impact shocks by the soft unstressed body material of the composite cutter, whereas in the case of the highly stressed body of the all hard cutter these shocks recoil to the point of origin, often resulting in chipping and fracture of apparently sound material.

Another point of considerable economic importance in connection with these composite cutters is their extended life on productive work. It is possible to utilise the greater portion of the cutter material incorporated in the tool. After much service, and when the amount of blade projecting from the body has been considerably reduced, a

portion of the body between the blades should be removed by milling or slotting, as indicated in Fig. 2. This illustration shows three stages of re-cutting, and indicates the manner in which the operation should be performed so that the rigidity of the cutting elements is not impaired. It will be noted that this method is entirely opposed to the method frequently adopted of making cutters of this type with removable and renewable blades. The aim in this new development is the ready removal of the comparatively inexpensive body material to expose for service, as required, the new cutting material, in order that the fullest service may be obtained from what undoubtedly is the most costly part of the tool.

Specially Designed Roll Caliper.

THE growing demand for accuracy in the production of mechanical appliances is largely responsible for developments made in precision tools, but it is necessary that the development of appliances for checking the degree of accuracy produced should progress in parallel. A recent development of this kind is a roll caliper, by the Churchill Machine Tool Co., Ltd., which has been specially designed for checking straight and cambered rolls, and has been introduced as an appliance for this firm's roll-grinding machines. This roll caliper is shown in the accompanying illustration, from which it will be seen that it is supported

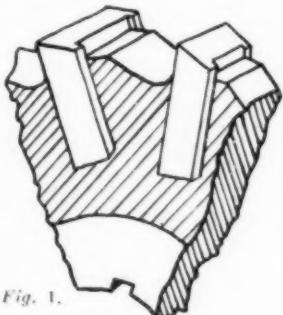
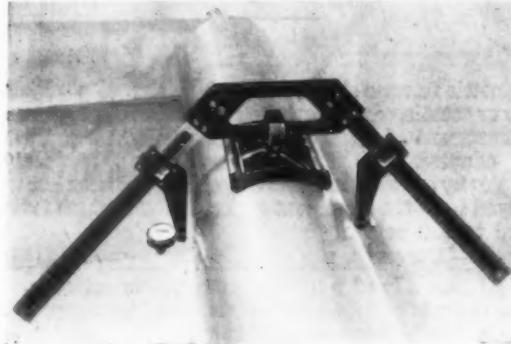


Fig. 1.



Fig. 2.



Roll Caliper.

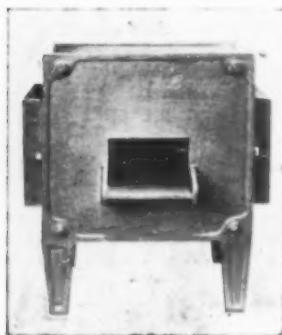
on the roll body by two accurately ground bars of sufficient length to ensure the caliper seating squarely on the roll. The caliper is supported by the bracket carrying the bars, and is free to swing only at right-angles to the axis of the bar.

The right arm of the caliper, it will be noted, carries an adjusting screw, and the left arm an indicating clock gauge. The brackets carrying the adjusting screw and the clock gauge can be set along the arms by graduations, corresponding with different roll diameters.

In operation for parallel rolls the movement of the caliper from end to end enables the parallelism to be checked, while with cambered rolls the different positions of the caliper directly indicate on the dial the amount and regularity of the camber, either concave or convex. This instrument is obtainable in two sizes, No. 1 size having a roll capacity from 9 in. diameter as the minimum to 30 in. maximum diameter, while with No. 2 size the diameters of roll within its capacity vary from 15 in. to 40 in. as the maximum. The maximum camber shown by the dial indicator is $\frac{1}{16}$ in., and this is applicable to each size.

Soldering Iron Heater.

THE accompanying illustration shows a "Globar" equipped soldering iron heater, which has been specially designed and constructed for use in engineering and other industries in which soldering irons are requisite. It represents one of the latest developments arising from the results of research work in connection with non-metallic heating elements, the application of which has been instrumental in simplifying the problem of developing high temperatures in furnaces or other installations specially designed for experimental or production work. In addition to being easily installed and readily replaced, these heating elements develop high temperatures, and yet occupy little spaces, and as there are no products of combustion to be considered, improved working conditions are the result.



"Globar" Equipped Soldering Iron Heater.

The heater illustrated has a hearth 4½ in. by 5 in., with a door opening 4½ in. by 1½ in. It is fitted with two "Globar" non-metallic heating elements, 6 in. long and ½ in. diameter, which are connected two in series for operation on 200/240 volts circuits. The total load on the heater is 1,600 watts, and it can be conveniently operated from any standard heater plug. The temperature of the heater enables a 2 lb. soldering iron to be heated adequately in 4 mins. The equipment is ready for instant operation, and effective economical control is one of its features.

A Recuperative Rotary Electric Furnace.

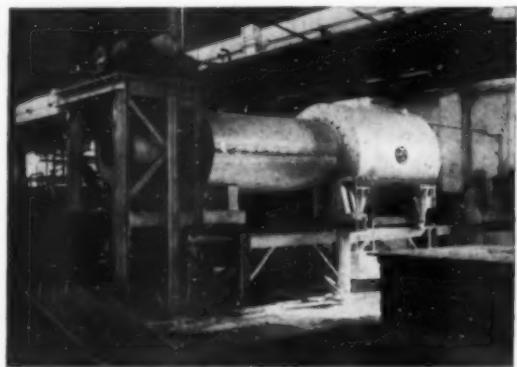
THE electric furnace shown in Fig. 1 illustrates a "Birlec" rotary or rotating drum furnace used for annealing or other heat-treatment of small metal products. In construction it is adapted to operate on continuous recuperative principles by enabling an exchange of heat between hot work conveyed from the treatment region to work which is being carried to this region.

This furnace which has a maximum rating of approximately 30 k.w., is of a special recuperative rotating, concentric drum type. Utilisation is made of the counter-flow principle, in which the material to be treated is fed into an inner drum from a hopper, and is propelled along this drum by a helix towards the heated end of the drum. Having travelled the full length of the inner drum into the heating zone, the material falls by gravity into the outer drum, and returns into the annular space between the two drums, again being propelled by a helix until it is finally discharged through a chute in the bottom of the furnace. During the return flow the heated work moves in contact with the walls of the inner cylinder, containing relatively cold work, and as the inner cylinder is made of heat-conducting metal, heat is absorbed by the incoming work during its travel towards the heating chamber itself, thus resulting in a considerable saving of energy.

The method of construction adopted facilitates access to the rotating drum and the heating elements. The insulated casing of the recuperative portion of the drum is made in two halves—the upper half of which can be turned back at its hinge, exposing the drum for inspection. In addition, the cylindrical structure containing the heating elements is supported on rollers, and can be moved horizontally away from the rotating drum, leaving the centre of the drum exposed and permitting of free access to the heating elements. In order that the rotating

drum and its load will have adequate support, the charging end has a trunnion which is supported by external bearings. Intermediate bearings are also provided, and these, together with the hopper-end bearings, serve to support the drum when the heater-end trunnion is left unsupported by withdrawal of the furnace itself.

The driving gear, which consists of motor, reduction gearing, and variable-speed gear, is mounted at the charging



Rotary Drum Furnace for Annealing or Heat-treatment of Small Metal Products.

end of the furnace on a raised platform to allow of free access to the charging hopper and the discharge chute.

A furnace corresponding to that shown in the illustration has been installed at Messrs. I. C. I. Metals, Ltd. (Kynochs), for annealing cartridge cases, and as a result of official tests made, it has been found that the consumption of electrical energy, which was guaranteed as 95 units per ton, gave an actual result of 64 units per ton, allowing for all standby losses. It is interesting to note that this relatively low consumption resulted when annealing on days only, whereas the guaranteed figure was for continuous running.

A New Electrode.

A CONSIDERABLE advance has been made in the development of alloy welding by the recent introduction of the "Cresta" electrode by the Alloy Welding Processes, Ltd. Remarkable elongation has been obtained in the tests which have been made with this electrode. In twelve test-pieces the elongation obtained between points 1 in. apart—i.e., covering the weld metal—never fell below 33%, and it reached as high a figure as 36%. This elongation was gained with an entire absence of porosity. The tensile strength of the material it deposits is 27–28 tons.

Theoretically, the perfect weld should possess characteristics equal in every respect to the metal being welded—i.e., the tensile strength, ductility, and resistance to fatigue should be similar, and the chemical composition should not vary, but, having obtained the theoretically perfect electrode, it is necessary to appreciate that the metal deposited is, in theory, a casting, which has not been subjected to the refining action of the "working," resulting from the heating and rolling operations. This difference will, undoubtedly, call for some slight variation in the specification of the weld metal, but the casting theory may, to a very great extent, be regarded as a bogey.

Tests are now being carried out by various firms in connection with this new electrode, and confidence is freely expressed that an electrode is now available which can be safely used for the welding of pressure vessels, and which will have a considerable influence on the continued development of electric arc welding.

Some Recent Inventions.

CHARGING CUPOLAS MECHANICALLY.

IT is generally recognised that the quality and character of the molten metal obtained from a cupola is dependent upon the care exercised in the distribution of the charge. The necessity for regular and uniform distribution of the charge is common to all shaft furnaces, and, in the case of cupolas, many foundrymen hold the opinion that the operation is best performed by hand methods. This applies to charging the material into the cupola shaft, as mechanical appliances have long been in use for collecting the required components of the charge and for raising the material to

a pivoted cover adapted to move in an approximately horizontal plane in opening and closing. The charging bucket is adapted to be used with the device. It is supported by straps or hangers A from an overhead runway B, in Fig. 2, passing directly over the line of cupolas. This runway permits loaded buckets to approach from the stockyard in which they are loaded. The bucket may have trunnions, and is fitted with double flap doors, pivoted and held normally in closed position by straps C C. These straps are pivoted to a block, which is adapted to slide in a special slideway on the side of the bucket.

A floating chair D, in Fig. 2, is carried on three vertical guides, and, being supported by chains passing round pulleys, is counterbalanced by weights, so that normally

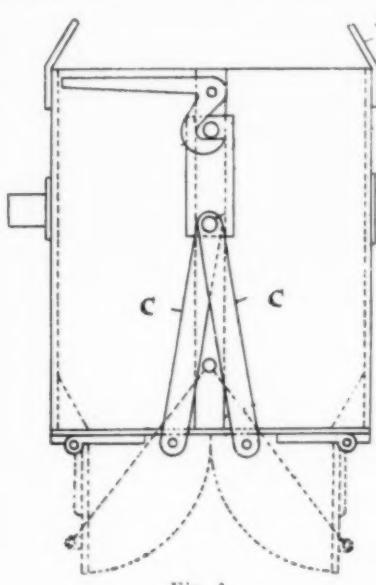


Fig. 1.

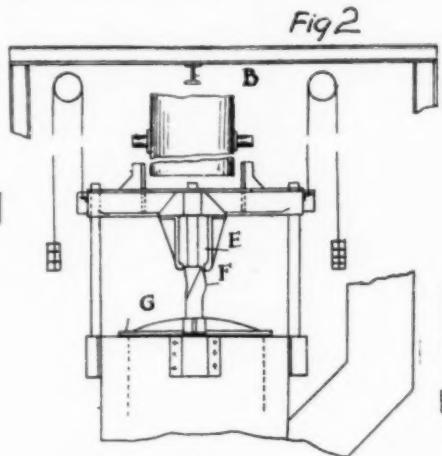


Fig. 2

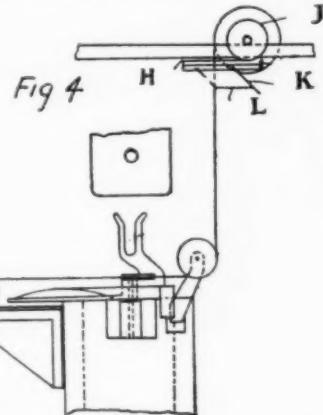
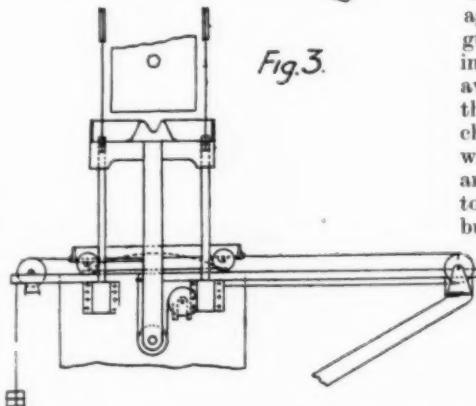


Fig. 4

Fig. 3.



the chair floats in its top position against stops on the guides. The guides are so made that the bucket in its travel along the runway avoids these tops and also clears the top of the floating chair. The chair has a central space through which the bucket may be lowered, and it carries trunnion supports to engage the trunnions on the bucket. A fitting E, secured to the chair, is adapted, as the chair is pressed downwardly by the continued descent of the bucket, to rotate the member F, and so swing the cover G horizontally to open the furnace. As the bucket is raised, after

discharge, the upward movement of the chair, under the action of the counterweights, returns the cover to the closed position. In a modification, the cover is mounted on wheels, as in Fig. 3, and is moved to one side on rails as the chair descends, counterweights being provided to return the cover to closed position when the bucket is lifted after discharge. Further constructions are described, in which the cover is formed in two pivoted halves, adapted to open downwardly or upwardly as the chair descends, and close again as the bucket is withdrawn. Fig. 4 shows a modified form of apparatus, in which the chair is omitted, the cover being swung horizontally to the open position by the engagement of a rack H mounted on the trolley E carrying the bucket, with a fixed pinion J adapted to operate the cover through a chain passing over sheaves and attached to a counterweight. The rack, in its normal position, clears the pinion, but is raised to engage the pinion corresponding to the furnace to be charged by linkwork K L operated by a handle.

328,258. JOSIAH ROBINSON, Clive Buildings, Calcutta, India, Patentee. Messrs. Boult, Wade and Tennant, Agents, 111/112, Hatton Garden, London, E.C. 1. April 22, 1930.

the charging-door level. There is no doubt that unless labour is carefully supervised charging by hand is not likely to be more regular than mechanical charging, and the latter method offers economical advantages.

Mechanical charging methods have developed considerably during recent years, and a wide variety of devices have been designed with a view to completing the cycle of operations from the storage bins to the mechanical delivery of charges to the cupola. Apart from detailed mechanical variations, they can be classified as devices involving skips or buckets which tilt, or as drop-bottom buckets.

A recent development of the latter type has been designed which has some interesting features. It is applicable for large foundries in which two or more cupolas are arranged in a line, and which are equipped with overhead trackways for carrying a charging bucket from the storage bins or stockyard to one end of the line. This new device more particularly concerns a method for charging any one of the cupolas in the line, the charging bucket avoiding or passing over any cupola or cupolas earlier in the line, which it is not intended to charge at the time, and automatically removing the cover of the selected cupola and delivering the charge.

The object of this device is to reduce as far as possible the need for individual supervision in charging, with the possibility of uncertainty in the proper correlation and sequence of operations under human control. A suitable type of bucket for use with a floating chair is illustrated in Fig. 1, while Fig. 2 shows a front elevation of the top of a cupola, fitted with automatic cover, operating means, and

Business Notes and News

Inaugural Dinner at Runcorn.

The chemical staff of the Chemical and Metallurgical Corporation, Astmoor Works, Runcorn, have recently formed a group membership of the British Association of Chemists, and an inaugural dinner of the group was held recently at the Waterloo Hotel, Runcorn. Mr. Arnatt, the managing director of the company, was the guest of the evening. Following the dinner, Mr. Crabtree referred to the energy, enthusiasm, and persistence with which Mr. Arnatt had tackled and overcome the difficulties which surrounded him when he took over control of the company.

Mr. Arnatt, replying, expressed his pleasure in being present at this inaugural meeting of the works members of the British Association of Chemists. He agreed the company had made great progress within the last few months, and quoted relative figures to show what had already been accomplished. He was not prepared to accept the credit, all had done their share, "but," stated Mr. Arnatt, "we must not forget there is still a future before us. When a struggle has been won there is sometimes a tendency to go easy, and that is the dangerous time. There are always newcomers eager, alert, and fresh for attack, and above all else, we must avoid stagnation, for stagnation, sooner or later, leads to defeat." Mr. Arnatt officially welcomed two new members of the staff, Mr. Riley, the new head of the Research Department, and Dr. Bott, also of the Research Department.

Referring to the evolution of Astmoor Works from the humble beginnings, Mr. Casson stated that to-day they had at Astmoor a works which, in its own line, was, from scientific, engineering, and chemical engineering standpoints, probably second to none in the world. The need of increased efficiency was emphasised by Mr. Beesley. From his experience, he stated, the plants at Astmoor compared favourably with any in the country.

In proposing the toast of the British Association of Chemists, Mr. Howie said that mutual interest, mutual trust, and mutual development were the best allies to help in the fight against stagnation, a real danger stressed by the earlier speakers. Mr. Looker gave a brief history of the origin of the Association, and said that it expressed, perhaps better than any other society, the restless vitality of those who earned their living by the profession of chemistry, and their determination to get some place in the sun.

New Deposits of Lithium.

Large deposits of lithium have been discovered in South West Africa. This metal is silver-white, and resembles sodium. It is softer than lead and the lightest of known metals, being able to float on naphtha as well as water. It melts at a temperature of 180° C., and when heated above this point it burns with an intensely white light. It is understood to be the chief element in a new aluminium alloy which is much lighter than pure aluminium. This new alloy is said to be nearly as strong as steel and capable of withstanding indefinite wear as a bearing material. The drawback to its more extended use hitherto has been the scarcity of the metal and its high cost of production, much of the lithium now produced having been extracted by a process which makes its market price about £7,500 a ton. The new deposits now being mined at Marienthal, near Windhoek, show an average yield of 4.59% of lithium oxide.

Diesel-Engined Omnibus.

A new advance in passenger transport has just been completed in the form of a heavy oil engined double-deck omnibus. This is a Crossley double-decker fitted with a Gardner heavy oil engine, which has just been supplied to the Leeds Corporation. A similar machine has since been ordered by the Sheffield Corporation.

Sometimes referred to as a "heavy oil" or "crude oil" engine, the Diesel engine is an internal combustion engine, very similar to the ordinary petrol engine, but is run on heavy oil. It has many marked differences. First, the fuel has so high a flashpoint that it is non-inflammable, and the danger from fire is practically eliminated. The price of the fuel used is less than one-third that of petrol, and owing to the design and characteristics of the Diesel engine the power developed is approximately twice that of a similar volume of petrol, resulting in a fuel economy of from 80% to 85%. This means that this Crossley vehicle can be run 100 miles for a fuel cost of 2s. 7d., against a similar type petrol bus cost of 16s. 6d., representing a fuel economy of approximately £400 a year.

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A New Technological Association.

A public company, limited by guarantee, has been registered with the object of purchasing a convenient site for a central building to provide offices and a comprehensive library for a number of important scientific and technical societies. It will be known as the Association for the Promotion of Co-operation between Scientific and Technical Societies and Institutions within the British Empire. The members of the council include Sir John Cadman, Dr. A. E. Dunstan, Sir Robert Hadfield, Mr. F. W. Harbord, Mr. H. Levinstein, Mr. E. Macfadyen, Mr. H. A. Reavell, Professor Joycelyn F. Thorpe, Sir Arnold T. Wilson, Sir Hugh Bell, Lord Brotherton, and Lord Wakefield, all of whom are closely associated with leading industrial or scientific organisations.

The building is expected to cost approximately £300,000, and it is probable that a site for it will be found in the Westminster district, where, it is stated, a building will be erected architecturally worthy of accommodating a magnificent collection of books. Already more than one-third of the £300,000 has been promised by industries anxious to develop the project, and it is confidently expected that the remaining amount will in time be forthcoming.

Among the organisations associated with the plan are the Institution of Mining and Metallurgy, the Chemical Society, the Society of Chemical Industry, the Institution of Chemical Engineers, the Iron and Steel Institute, the Institution of Petroleum Technologists, and the Rubber Institute.

Gold Mining in Wales.

A Government inquiry was opened on October 9 with a view to determining the conditions and prospects of gold mining in North Wales. Professor Henry Louis, president of the Iron and Steel Institute, is making the investigation, and gold-mining experts, engineers, and local authorities are co-operating. The Government have taken this action as a result of the depression in the Welsh mining industry, at the request of the local authorities, who presented a memorial to Mr. J. H. Thomas, in which the claim was made that "where honest effort at legitimate mining had been undertaken the percentage of success is higher than in any goldfield of like character."

It will be interesting to see what the prospects are of increasing the scope of this work. The mines at Dolgelley have been worked more or less continually since 1851, and Government returns from 1888 to 1911 show that nearly 300,000 tons of ore were mined and milled, from which 100,000 ounces of pure gold, valued at £368,847, were recovered. Eminent mining engineers have declared that there still exists in North Wales an area of 250 square miles which has as good showing of gold for the amount of work done as any similar area. The St. David mines in Merioneth were worked up to 1914, and wedding rings for the Queen, Princess Mary, and the Duchess of York were made from gold extracted here. Several tons of ore and gold quartz from the valley of the Mawddach have this week been sent to London to be assayed.

Endorsing National Certificates.

An arrangement has existed for the past six years, whereby, when a candidate for a *higher* national certificate in mechanical engineering at the termination of an *advanced* course, includes a specialised automobile engineering subject in his final examination, the signature of the President of the Institution of Automobile Engineers can be added to any certificate which may be awarded.

The arrangement has now been extended to *ordinary* certificates awarded at the termination of *senior* part-time courses. It has also been arranged to consider applications for approval of *supplementary* senior part-time courses with a view to the endorsement of automobile engineering subjects on ordinary certificates previously awarded at the termination of courses of a more general type. Such applications should be addressed in the first instance to the Board of Education, and requests for the addition of the signature of the President of the Institution of Automobile Engineers to ordinary certificates awarded or endorsed under these conditions should be made to the Institution of Mechanical Engineers at the time when the results of final examination are submitted.

With the September issue the *Edgar Allen News* has attained its hundredth number. It was first published with the intention of supplying useful information in regard to the materials, appliances, and methods employed primarily in the manufacture of finished and semi-finished steel products. This number is an excellent example of the manner in which the original intention is maintained. It is both interesting and informative, and we are of the opinion that it is well worth 6d. per copy.

Some Contracts.

Orders amounting to nearly half a million pounds sterling have just been placed by the Newcastle-upon-Tyne Electric Supply Co., Ltd., in connection with their new power station at Dunston-on-Tyne. The contracts include boiler installations, condensing plant, and auxiliaries, and they have been largely placed on the North-East Coast. Messrs. Clarke, Chapman and Co., Ltd., of Gateshead, will provide six of the boilers at a cost of approximately £225,000, the remainder being supplied by Messrs. Babcock and Wilcox. Arrangements have been made with Messrs. Babcock and Wilcox under which they will sub-contract part of their order to Messrs. Clarke, Chapman, representing a further £50,000. Messrs. Richardsons, Westgarth and Co., Ltd., of West Hartlepool, have received an order for the condensing plants and auxiliaries required for the power-station. The value of this order is over £90,000. It is understood that the bulk of the material required for the work will be produced locally, so that its effect will be felt in the iron trade of the North-East Coast.

Vickers, Ltd., are to build a large flying boat for the Civil Aviation Department of the Air Ministry. The greater part of the hull will be of stainless steel, which experience has shown to be specially suitable, and will be built in the Sheffield works. The boat is expected to weight 33 tons when loaded, the hull of which will be 100 ft. long and 18 ft. high, and is designed to accommodate forty passengers. The machine, it is stated, will be of the monoplane type having a span of 174 ft., and will have a petrol tank of 2,250 gals. capacity. Six Rolls-Royce engines each 900 h.p. will provide the power.

Vickers-Armstrong, Ltd., Barrow, have secured a contract from the Cunard Steamship Company for the overhaul of the propelling machinery and the renewal of the high-pressure turbine casings of the Western ocean liner *Carinthia*, built in Barrow in 1925. The alterations will increase speed and reduce fuel consumption. The *Carinthia* is now on passage from New York to Liverpool, and is due in Barrow next.

The South African Railways and Harbours have placed with the Paterson Engineering Co., Ltd., of Kingsway, W.C. 2, a contract for ten water-softening plants for installations at locomotive depots at various stations between De Aar and Matjiesfontein on the Capetown-Pretoria main line. The capacity of the ten plants contracted for will vary in size from 8,000 to 16,000 gals. of water per hour, and they will all be of the vertical cylindrical type. The equipment will include the "Paterson" by-pass. "Osilametre" feed gear for the lime and soda ash reagents, which add these chemicals automatically in proportion to the varying flow of the water, but at the same time when the hardness varies, allows the supply of the reagent to be adjusted instantly while the plant is in operation. Each of the plants will have six hours' settling capacity, due to the high magnesium content of the water in the sections being covered.

The Egyptian State Railways have recently awarded two contracts for railway equipment. An order for buffers and buffer stops has been placed with Geo. Turton Platts and Co., Ltd., Sheffield, at a total cost of £635 delivered f.o.b. Liverpool or Birkenhead. A further order has been placed with the English Steel Corporation, Ltd., Sheffield, for helical buffering springs at a cost of £387 10s., delivered f.o.b. Liverpool or any English port.

The Albion Motor Car Co., Ltd., of Scotstoun, Glasgow, have received a repeat order from the Cape Electric Tramways for six Albion buses for use in connection with their tramway system at Port Elizabeth.

John I. Thornycroft and Co., Ltd., Basingstoke, Hants., have received the following orders for vehicles:—The Buenos Aires and Pacific Railway, six 3-ton six-wheeled chassis; the Central Uruguay Railway, three 30-cwt. chassis; the China Bus Company of Hongkong, three 20-seated omnibus chassis; Boots, Ltd., of Nottingham, three 6-ton six-cylinder freight chassis; the Distillers' Co., Ltd., three 4-ton lorries; also repeat orders for one or more Thornycroft vehicles have been received from Talbot Serpell Transport Co., Ltd., Reading; Belfast Co-operative Society, Ltd.; Joseph Crosfield and Sons, Ltd.; Northern Butchers' Hide and Skin Co., Ltd., Leeds; Allen Everitt and Sons, Ltd., Smethwick.

A contract has been placed with C. A. Parsons and Co., Ltd., of Heaton, Newcastle, for a large electrical plant for Canada. It is for the provision of the generator equipment for a 2,500,000-bushel grain elevator, which is under construction at Fort Churchill, Hudson Bay, Canada. The estimated cost of the equipment is £100,000. The same firm has secured several large orders for electrical work recently, including a contract for three 50,000-kilowatt turbo-alternators for Dunston-on-Tyne power station, an 18,750-kilowatt turbo-alternators for the London Underground power station at Chelsea, and other orders in connection with the electrical change-over from 40 to 50 cycles in the national grid scheme.

Sir W. G. Armstrong, Whitworth and Co., Ltd., have secured a contract for three heavy-oil mobile electric power-houses and one heavy-oil electric locomotive for the Buenos Aires Great Southern Railway. The mobile power-houses generate electricity directly to the carriages of an electric train, obviating the pick-up or overhead system. Some months ago Armstrong-Whitworth established an oil-engine department for the manufacture of oil-engine generating machinery. They are thus fortunately placed for undertaking this class of work.

Swan, Hunter and Wigham Richardson, Ltd., have booked an order for a small passenger steamer for Yugo-Slav owners. It will be built at the Walker Neptune yard.

Vickers-Armstrongs are to overhaul the machinery for the Cunarder *Carinthia* at Barrow. This vessel was built at Barrow, and when delivered was specially fitted for luxury trips to the Mediterranean and round the world.

Complete electrical equipment for fifty tramcars for the Leeds Corporation Tramways has been ordered from the General Electric Co., Ltd., Magnet House, Kingsway, London, and the company's standard apparatus is being supplied. Each equipment consists of two G.E.C. standard traction motors, type W.T. 288, each developing 50 h.p. on the one-hour rating, 500 volts two-drum type controllers (for series-parallel control) arranged for rheostatic braking circuit, breakers, current collector gear, and resistances.

Control equipments numbering 160 for new motor and trailer cars of the London Electric Railways are to be supplied by the British Thomson-Houston Co., Ltd., Rugby. It will be remembered that in January, 1928, this company received the order for 561 control equipments for the motor and trailer coaches constructed under Lord Ashfield's scheme for speeding up and increasing the travelling facilities on the London Underground Railways. All the latest improvements are embodied in the design of the new equipments, which include circuit breakers, reversers, master controllers, cut-out switches, contactor control gear, relays, switchboards, etc.

Three Rolls-Royce H. aero engines have been ordered by the United States Government. The engines are of 825 h.p. Vee type, of twelve cylinders, and weighing 1,460 lb.

A contract for a 20-ton wagon coal hoist for Penarth Dock has been placed by the G.W.R. Co. with Fielding and Platt, Ltd., Gloucester.

An order for mining drillers has been placed by the Russian Trade Delegation with the Scottish firm of Andrew Kyle and Co., Galston, and an order for mining machinery to the value of over £100,000 with Mavor and Coulson, Ltd., Bridgeton, Glasgow.

The Staveley Coal and Iron Co. have secured contracts for the supply of 1,800 tons of cast-iron pipes for the Gas Light and Coke Co., 900 tons for the Colne Valley Waterworks, and 682 tons for South Africa.

Orders for the supply of aeroplanes at a total cost of £70,000 have been received by the De Havilland Aircraft Co. All the machines will be Moths and will be used by the British R.A.F. and the New Zealand and Chinese Air Forces for training and general service purposes. Eighty-three of the machines are for the R.A.F., eight, including one seaplane, for New Zealand, and ten for China.

IRON AND STEEL REPORT.

A FEATURE which it is impossible to ignore in surveying the iron and steel trades during the past month is that the eagerly-awaited autumn improvement has shown no indication of developing either in iron or steel.

Relatively, the position seems to be even worse in the case of steel than in foundry iron. Certainly, the demand for the former during the past few weeks, so far as the heavy sections of the trade are concerned, has been dwindling, and it is extremely doubtful if, in the aggregate, the movement of steel has been equal to that of the summer months. Up to a point, of course, it is probable that new buying by steel consumers has been held up pending the mid-October meeting of British makers. Whether or no prices will be reduced or rebate concessions increased is not known at the time of writing. The fact remains, however, that consumers have been more or less confidently awaiting one or the other of these developments, and have been regulating their commitments accordingly. Where old contracts have expired or have approached that stage users have been content to purchase fresh supplies to meet early needs only, and have rigorously abstained from entering into fresh forward contracts.

The most disquieting feature of the situation, however, and the one which gives a more direct pointer to current conditions at the consuming end of the steel trade, is the extremely unsatisfactory rate at which users have been specifying for deliveries of material against running contracts. This applies pretty well to all classes—joists and sections, plates of all descriptions, and all sizes of bars. On the whole, locomotive builders are less busy than they were earlier in the year, and the late new contracts of any importance have been much less numerous. The result has been reflected in a declining demand for boiler and frame plates and other materials, and also smaller specifications for deliveries against running contracts. With very little support from boiler-makers, this class of plates has recently been a weakening market, and to day's rates are no better than £9 10s. to £9 12s. 6d. per ton, according to points of delivery. Shipbuilding material also is only moderately active, and the same may be said in respect of constructional steel. In the latter branch of engineering a good deal of work for which tenders have been invited is, for one reason or another, held up, and consequently many constructional firms are short of work. As has been indicated, so far there has been no change in controlled prices, and the only remaining alteration has been in re-rolled bars. These, for some time now, have been a weak market, and £7 12s. 6d. per ton is about the top figure that is now being indicated, with more than a possibility of business being placed at below this. Perhaps the only relatively bright spot has been alloy steels, the demand for which on several occasions during the past month has been on a fair scale.

Continental steel materials, with the virtual collapse of the Cartel selling arrangements, have reached new low levels, and keen cutting is the rule where business is offering. Of this, however, there is not much, and few important orders for either finished or semi-finished products have lately been reported in British markets.

There has been very little in the way of development in the foundry iron market. No price changes have occurred since last report, but as the likelihood of higher values is regarded as being more remote than a movement in the opposite direction, users are restricting fresh purchases to deliveries about a month ahead. In this section the movement is about up to the level of the past few months with, however, little sign of immediate improvement. Fairly active conditions at the pipe foundries, which are associated with one or two of the leading pig-iron producers, mean the absorption of a fair proportion of the make, and in this way stocks of iron at the blast-furnaces are kept down. In other cases, however, makers are finding it extremely difficult, in spite of a reduced output, to prevent stocks reaching unwieldy proportions.

NON-FERROUS REPORT.

THE non-ferrous market remains dull. In every section there has been an increasing decline in prices. It was generally accepted some time ago that prices had reached rock bottom, but with the conditions prevailing at present it is not advisable to depend upon calculations of this nature. A comparison with the market prices at the beginning of the year will indicate the extent of the reduction that has taken place. It was confidently expected that low prices would attract more buyers with the object of accumulating stocks, but they are more inclined to operate on a supply and demand basis in the hope that further reductions will take place. In spite of the restrictions imposed upon production, the supplies continue to exceed the demand, and until production is further restricted or demands are increased this will continue to affect the stability of the market.

The successive reductions in the prices of copper have not influenced the industrial demand to any appreciable extent. No doubt the excessive stock on the market is in a measure responsible, and the prospects of a further decline prevents buyers taking advantage of a weak market. The effect of the gradual decline is noticeable in the report issued by the directors of the Rio Tinto Co., who state that owing to the fall in the price of copper and the fall in demand for other commodities of this company, there has been a shrinkage of 34% in the gross trading profit for the first six months of this year.

The demand for tin has also been subdued. At the reduced level of values there has been no keenness to purchase, and with a possible reduction in Straits tin the market remains weak, with prices at their lowest since before the war. In order to appreciate the position, Mr. E. J. Bryan, chairman of Kamunting Tin Dredging and the Panguga River Tin Concessions, has issued a letter, in which he finds it necessary to state that tin companies do not produce metallic tin; they produce tin concentrates which are smelted into metallic tin by the smelters. The smelter sells the metallic tin daily at market prices, and on a cash basis, and the London market price for the metal is the basis for calculating the price paid to the producer for the tin ore. Under present conditions the smelter gets a fixed price per ton of metal produced, and in consequence fluctuations in the price of tin do not affect him directly.

The price of lead which has been fairly steady for some time has also been affected by the general decline, and as a result of a lower price, business has been a little more active, but there has been little interest displayed by cable-makers. Supplies are ample to meet all possible demands.

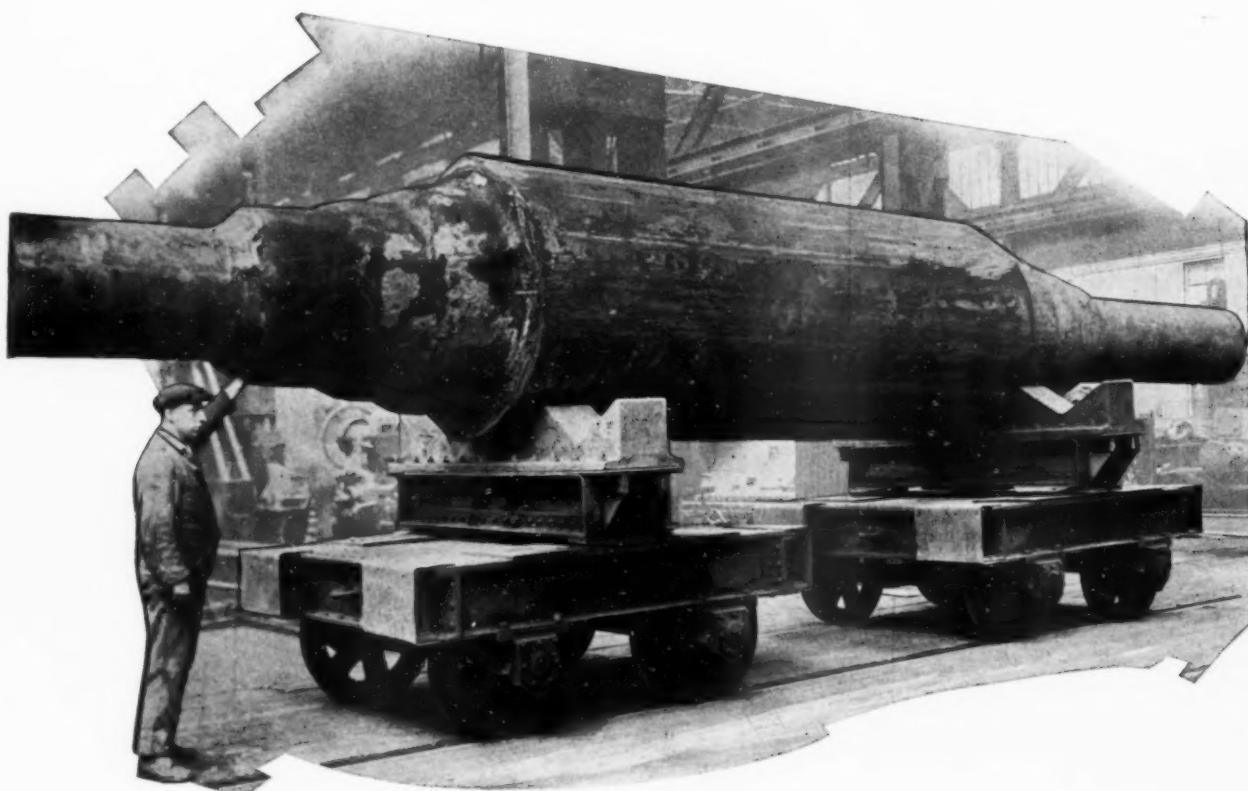
The outlook in regard to spelter is poor, and this, in keeping with other non-ferrous metals, has lost ground, and there is a possibility of even lower prices being recorded. The question of curtailing the supply has been discussed, but little seems to have resulted, and many consider the possibilities somewhat remote. The price ruling at the moment involves a loss on production, and unless the zinc cartel can establish real control many producers will close down.

Gold Medal Award of Junior Institution of Engineers.

We have been informed that Mr. Herbert Southern, one of the directors of G. P. Wincott, Ltd., metallurgical furnace and constructional engineers, has recently been awarded the Gold Medal of the Junior Institution of Engineers for a paper he gave in March last, entitled "Industrial Chimneys and Flues." It is interesting to note that Mr. Southern has already received the Vickers Gold Medal and prize, as well as two other silver medals for papers he has given on the historical development and the design and construction of industrial furnaces.

We learn that Messrs. Ridsdale and Co., consulting metallurgists and analytical chemists, 3, Wilson Street, Middlesbrough, whose name is well known in connection with British Chemical Standards, in addition to their regular analysis of materials for the iron, steel, foundry, and non-ferrous industries, have recently been approved by the Air Inspection Directorate for the chemical analysis of metallic materials.

FORGINGS like the one shown—it is an electrical rotor forging, weighing 69 tons, and the diameter of the barrel is 53 $\frac{1}{2}$ ", the length being 30ft—are constantly to be seen in the shops of the English Steel Corporation.



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MARKET PRICES

ALUMINIUM.		GUN METAL.		SCRAP METAL.	
99% Purity	£95 0 0	Commercial Ingots	£65 0 0	Copper Clean	£38 0 0
Castings, 2.L5 Alloy	lb. 1/3-1/8	*Gunmetal Bars, Tank brand,	"	Braziers	5 0 0
" 2.L8	1/4-1/9	1 in. dia. and upwards..	lb. 0 1 0	Wire	
" Silicon	"	"	0 1 2		
ANTIMONY.		LEAD.		Heavy Steel—	
English	£38 0 0	Soft Foreign	£16 0 0	S. Wales	2 15 0
Chinese	2 10 0	English	17 7 6	Scotland	2 10 0
Crude	22 0 0			Cleveland	2 7 6
BRASS.		MANUFACTURED IRON.		Crown Bars—	
Solid Drawn Tubes	lb. 10 1/2	Scotland—	£10 5 0	Crown Bars	
Brazed Tubes	lb. 12 1/2	N.E. Coast—		Rivets	11 10 0
Rods Drawn	" 10d.			Best Bars	11 5 0
Wire	" 8 1/2d.			Common Bars	10 15 0
*Extruded Brass Bars	" 5 1/2d.	Lancashire—			
COPPER.				Crown Bars	10 7 6
Standard Cash	£43 17 6			Marked Bars	12 10 0
Electrolytic	46 10 0			Unmarked Bars	
Best Selected	46 0 0			Nut and Bolt Bars	9 2 6
Tough	45 10 0			Gas Strip	11 2 6
Sheets	75 0 0			S. Yorks.—	
Wire Bars	47 10 0			Best Bars	11 0 0
Ingot Bars	47 10 0			Hoops	12 0 0
Solid Drawn Tubes	lb. 11 1/2d.				
Brazed Tubes	" 11 1/2d.				
FERRO ALLOYS.		PHOSPHOR BRONZE.		SPELTER.	
†Tungsten Metal Powder	lb. £0 2 6	*Bars, Tank brand, 1 in. dia. and	upwards	G.O.B. Official	
†Ferro Tungsten	" 0 2 3	upwards	lb. 1/-	Hard	£11 5 0
‡Ferro Chrome, 60-70% Chr.		*Cored Bars	" 1/2	English	15 2 6
Basis 60% Chr. 2-ton		Strip	" 1/0 1/2	India	13 5 0
lots or up.		Sheet to 10 W.G.	" 1/1	Re-melted	13 5 0
2-4% Carbon, scale 11/-		Wire	" 1/1 1/2		
per unit	ton 30 10 0	Rods	" 1/0 1/2		
4-6% Carbon, scale 7/-		Tubes	" 1/5 1/2		
per unit	" 23 2 6	Castings	" 1/1 1/2		
6-8% Carbon, scale 7/-					
per unit	" 22 12 6				
8-10% Carbon, scale 7/-					
per unit	" 22 0 0				
‡Ferro Chrome, Specially Re-					
fined, broken in small					
pieces for Crucible Steel-					
work. Quantities of 1 ton					
or over. Basis 60% Ch.					
Guar. max. 2% Carbon,					
scale 10/- per unit	" 33 0 0				
‡Guar. max. 1% Carbon,					
scale 13/6 per unit	" 37 15 0				
‡Guar. max. 0.7% Carbon,					
scale 15/- per unit	" 41 10 0				
‡Manganese Metal 96-98%					
Mn.	lb. 0 1 3				
†Metallic Chromium	" 0 2 7				
‡Ferro-Vanadium 25-50%	" 0 12 9				
‡Spiegel, 18-20%	ton 7 5 0				
Ferro Silicon—					
Basis 10%, scale 3/-					
per unit	ton 5 17 6				
20/30% basis 25%, scale					
3/- per unit	" 7 17 6				
45/50% basis 45%, scale					
5/- per unit	" 11 10 0				
70/80% basis 75%, scale					
7/- per unit	" 18 0 0				
90/95% basis 90%, scale					
10/- per unit	" 25 6 0				
‡Silico Manganese 65/75%					
Mn., basis 65% Mn..	" 14 0 0				
‡Ferro-Carbon Titanium,					
15/18% Ti	lb. 0 0 6				
‡Ferro Phosphorus, 20-25%	ton 15 12 6				
FUELS.		SWEDISH CHARCOAL IRON AND STEEL.		STEEL.	
Foundry Coke—		Pig Iron	£6 0 0 to £7 10 0	Ship, Bridge, and Tank Plates	
S. Wales Export	£1 7 0 to £1 17 0	Bars, hammered,		Scotland	£8 15 0
Sheffield Export	0 17 0 to 0 18 6	basis	£17 10 0 .. £18 10 0	North-East Coast	8 15 0
Durham Export	1 4 0 to 1 6 0	Blooms	£10 0 0 .. £12 0 0	Midlands	8 17 6
Furnace Coke—		Keg steel	£32 0 0 .. £33 0 0	Boiler Plates (Land), Scotland	10 0 0
Sheffield Export	£0 17 0 to £0 18 6	Faggot steel	£20 0 0 .. £24 0 0	" " (Marine)	10 10 0
S. Wales	1 1 0 to 1 1 6	All per English ton, f.o.b. Gothenburg.		" " (Land), N.E. Coast	10 0 0
Durham	0 14 0 to 0 14 6			" " (Marine)	10 10 0
HIGH SPEED TOOL STEEL.				Angles, Scotland	8 7 6
Finishes Bars 18% Tungsten.				" North-East Coast	8 7 6
Extras				" Midlands	8 7 6
Round and Squares, 1/2 in. to 1/2 in.				Joists	8 10 0
Under 1/2 in. to 1/2 in.				Heavy Rails	8 10 0
Round and Squares 3 in.				Fishplates	12 0 0
Flats under 1 in. x 1/2 in.				Light Rails	8 17 6
" " 1/2 in. x 1/2 in.				Sheffield—	
				Siemens Acid Billets	9 10 0
				Hard Basic	9 12 6
				Medium Basic	8 2 6
				Soft Basic	6 10 0
				Hoops	9 15 0
				Manchester—	
				Hoops	9 15 0
				Scotland, Sheets 20 W.G.	9 10 0
TIN.		HIGH SPEED TOOL STEEL.		TIN.	
Standard Cash		Finishes Bars 18% Tungsten.		Standard Cash	£119 5 0
English		Extras	lb. 3/-	English	120 5 0
Australian		Round and Squares, 1/2 in. to 1/2 in.	3d.	Australian	121 0 0
Eastern		Under 1/2 in. to 1/2 in.	1/-	Eastern	126 2 0
Tin Plates I.C. 20 x 14	box	Round and Squares 3 in.	4d.	Tin Plates I.C. 20 x 14	17/-
Block Tin Cash		Flats under 1 in. x 1/2 in.	3d.	Block Tin Cash	£122 0 0
ZINC.		" " 1/2 in. x 1/2 in.	1/-		
English Sheets					
Rods					
Battery Plates					

* McKechnie Brothers, Ltd., quoted Oct. 9.

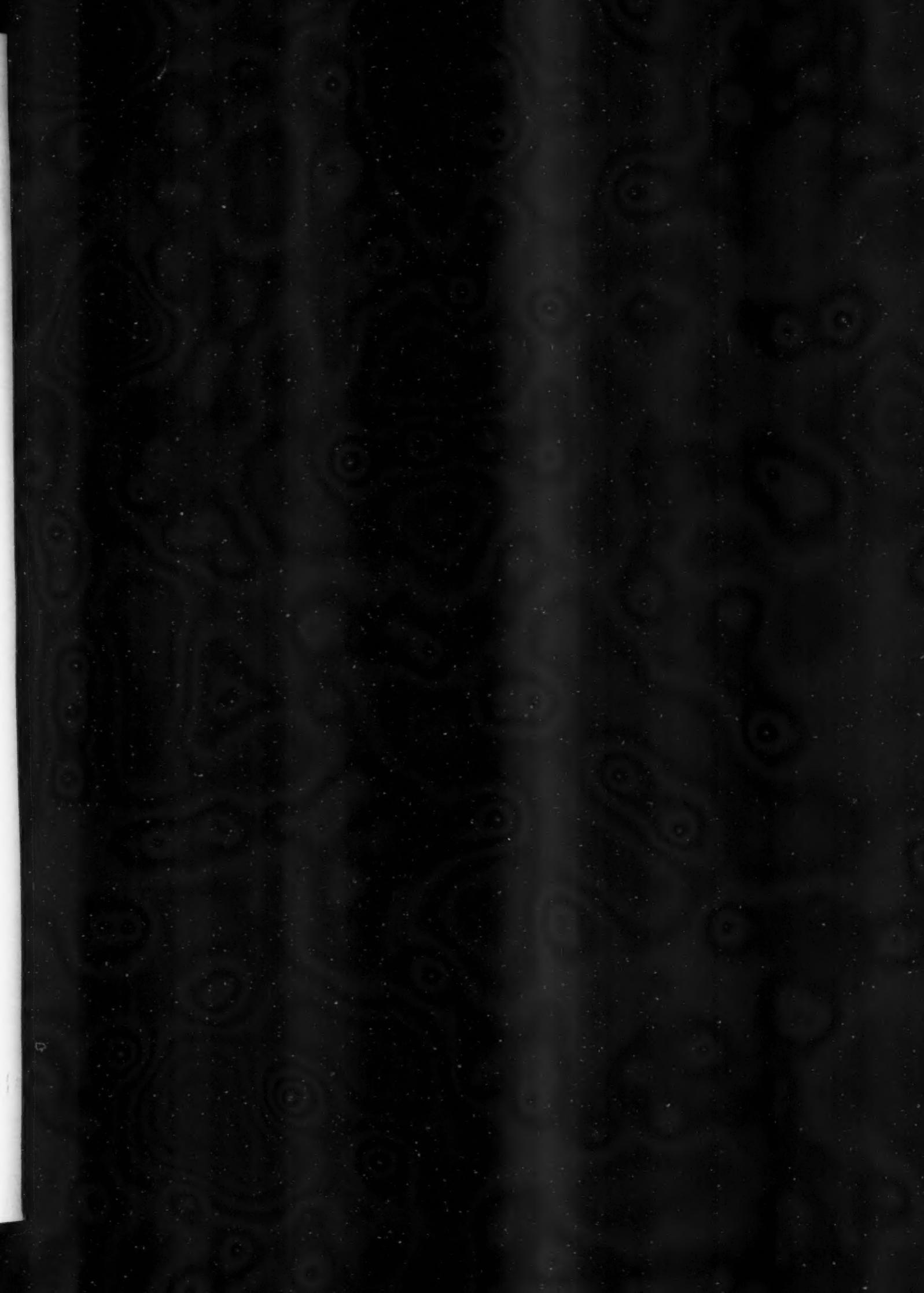
† C. Clifford & Son, Ltd., quoted Oct. 9.

‡ Murex Limited, quoted Sept. 8.

Subject to Market fluctuations, Buyers are advised to send inquiries for current prices.

Lancashire Steel Corporation's Current Basis Prices:—Wrought Iron Bars, £10 5s. 0d.; Mild Steel Bars, £7 17s. 6d.; Wrought Iron Hoops, £12; Best Special Steel Baling Hoops, £9 15s. 0d.; Soft Steel Hoops (Coopers' and Ordinary Qualities), £9; C.R. & C.A. Steel Hoops, £12 10s. 0d. to £13 10s. 0d.; "Iris" Bars, £8 15s. 0d. All Nett Cash. Quoted Oct. 9.

† Prices quoted Oct. 9, ex warehouse.





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patent

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Type GS. 1.

GP2. With tapered grooves extending half length of pin.

GP3. With parallel grooves full length, chamfered end for easy fitting.

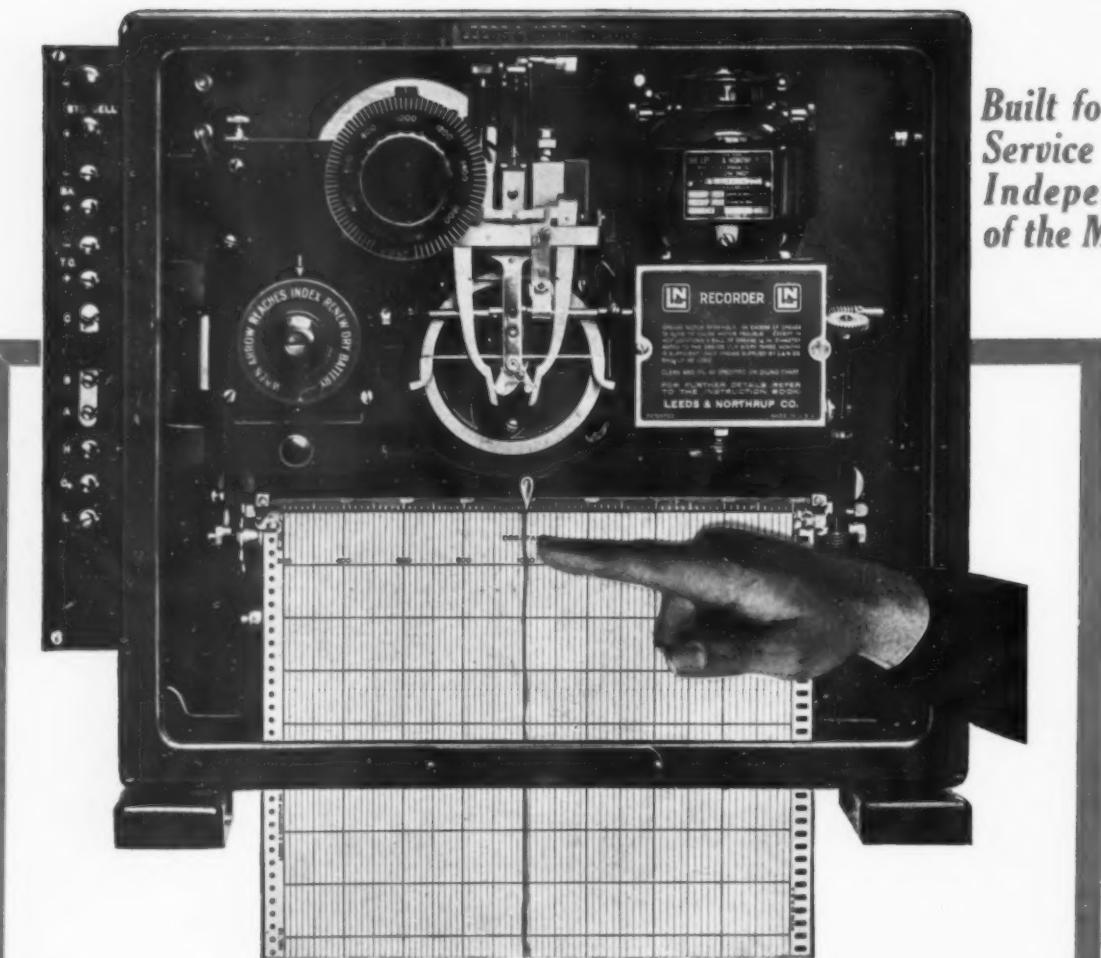
GP5. Centre grooved pin.
Grooves extend half length

GP7. With turned notches in ungrooved portion.



Grooved
Stud,
Type GS. 2.

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Sole Agents for the LEEDS & NORTHRUP CO.



FURTHER ALLOYS

As Alloying elements or as Deox
must be considered

Ferro-Vanadium.

Vanadium influences the properties of steel indirectly through its powerful deoxidising and scavenging effect, and directly as an alloy. A small amount may be dissolved in the ferrite, but the majority forms complex carbides with the cementite. Apart from its use in high-speed and special steels, the action of the vanadium is apparently exerted in its tendency to reduce grain size and also to cause a refinement in structure. The former is the outstanding characteristic of the ordinary vanadium and vanadium steels. From an engineering point of view vanadium may be considered as an intensifying agent, particularly when linked with chromium. A further analysis, which may be taken as typical, is as follows:—

Iron.	Vanadium.	Siliccon.	Manganese.	Aluminium.	Sulphur.	Phosphorus.	Carbon.
62.62	33.40	2.76	0.40	0.25	0.045	0.45	0.40

Ferro-Titanium.

Although not easily reduced in the blast-furnace under ordinary conditions, titanium, as ferro-titanium, is made in the electric furnace with varying proportions of titanium at comparatively low cost. This alloy is claimed to increase the strength of steel, but probably its indirect qualities rather than its direct effect on the mechanical properties of steel are of greater value. Indirectly it has a marked effect, as it combines readily with oxygen, and has also a strong affinity for nitrogen. In steel-making the titanium, in the form of ferro-titanium, is added to the ladle, replacing the aluminium and part of the usual ferro-silicon addition. As a rule, little, if any, titanium remains in the steel, but its effect is marked by greater soundness and improved strength, toughness, and wearing qualities. In some instances it is used in the form of ferro-carbon-titanium.

This alloy is guaranteed on its titanium content, varying between 10 and 12%, and is sold by the pound of the alloy. With higher percentages of titanium the alloy is sold per pound of titanium contained in it.

Typical Analyses

	Titanium.	Iron.	Carbon.	Silicen.	Sulphur.	Phosphorus	Manganese
Low grade	11.21	87.68	0.67	0.37	0.03	0.04	—
High grade.....	51.30	44.19	2.82	0.05	0.02	—	0.38

FERRO-CARBON-TITANIUM

A special grade of ferro-titanium alloy is made in which the carbon contents range between 5 and 7%, with titanium from 10 to 15%.

An average analysis of ferro-carbon-titanium, and sold per pound of alloy, is as follows:—

An average analysis of ferro-carbon-cremum, and sold per pound of alloy, is as follows:—

Tungsten.

Tungsten in the absence of carbon has no very marked effect upon the mechanical properties of iron, but in carbon steels it greatly increases the hardness and hardening power. One of the first notable instances in the use of tungsten to modify the properties of ordinary steel was the introduction by Musket of his special steel which contained 5 to 8% of tungsten and 1.5 to 2.3% of carbon, and which is self-hardening. In addition to its use in self-hardening and in high-speed steels, it is also used in steels for springs and permanent magnets.

NICKEL-TUNGSTEN-

Nickel.	Tungsten.	Carbon.	Silicon.
25 to 50	50 to 75	0.5 to 1.0	0.25 to 0.50

Nickel may be sintered in the manufacture. A straight nickel, or heat-treatment, is employed in the alloy steels. This is a nickel compound, containing elements such as chromium, molybdenum, and cobalt as components.

During recent years additional strength has been added in boiler and bridge. In comparison with old structures due to prolonged heating.

This alloying element, with other elements, such as molybdenum, nickel, etc.,

Ferro-nickel is su
nickel and iron conte

The improvement with increase in strength of chromium. A proper choice of alloy and responsiveness to either alloy when used.

The analyses of

Iron.
20 to 30
28 to 30

This alloy has a
ium. The main adva
is more easily fusible,
of aluminium.

Calcium.

ALLOYS USED IN STEEL MAKING

Deoxidisers. Several factors, operating in a variety of ways, are used to fix an exact amount of Alloy for a charge.

Nickel.

It may be said to have been the pioneer among the common alloys now used in steel manufacture. Straight nickel steel has remarkably good mechanical qualities when subjected to suitable heat treatment, is excellent for casehardening, and its machining qualities take a high place among steels. This alloy primarily influences the strength and ductility of steel in that the nickel, when compound, is dissolved directly in the iron or ferrite. In this sense it is distinct from such elements as chromium and manganese, which unite with and emphasise the character of the cementitic

In recent years there has been an increasing use of nickel steels in parts that require great strength and in which a heat-treating process is not practicable, such as plate steels used in bridge work. For casehardening steels the value of nickel has long been recognised. When combined with carbon steels, corresponding nickel steels show less susceptibility to brittleness when heated at the high temperatures often used in carburisation.

Nickel, as ordinarily issued, is over 99% pure. It is frequently used as an alloying element, as ferro-nickel, ferro-nickel-chrome, ferro-nickel-silicon, nickel-tungsten, nickel-chromium, nickel-chromium, etc.

FERRO-NICKEL.

Nickel is supplied with 25, 35, 50, or 75% of nickel. The balance of analysis outside the nickel contents being about:—

Carbon.	Silicon.	Sulphur.	Phosphorus.
0.85 ..	0.25 ..	0.015 ..	0.025 ..

FERRO-NICKEL-CHROME.

An improvement in ductility and toughness to carbon steel conferred by nickel can be combined with an increase in strength, surface hardness, and depth-hardening obtained by the influence of chrome. A proper combination of the two alloys will accentuate the density of structure, reliability, and toughness to heat-treatment, as well as confer distinctive properties not characteristic of either when used alone.

Analyses of ferro-nickel-chrome approximate between the following:—

Iron.	Nickel.	Chromium.	Carbon.	Other Elements.
29 to 30 ..	17 to 19 ..	51 to 52 ..	0.25 to 0.75 ..	0.10 to 0.20 ..
28 .. 29 ..	17 .. 19 ..	50 .. 51 ..	1.30 .. 1.80 ..	0.10 .. 0.20 ..

Calcium Silicide.

It has a powerful deoxidising influence, and is frequently used in preference to aluminium. The main advantage is due to the slag formed. As a result of the oxidation of calcium silicide it is less fusible, and is more readily eliminated in the ingot than that formed from the oxidation of aluminium.

Average Analysis.

Alum.	Silicon.	Iron.	C. Carbon.	Aluminium.	Magnesium.	Sulphur.
20 ..	38.40 ..	4.90 ..	0.87 ..	6.25 ..	0.27 ..	0.27 ..

SILICON-ALUMINIUM-MANGANESE.

Silicon.	Aluminium.	Manganese.	Carbon.	Iron.
25.0 ..	15.0 ..	58.0 ..	0.2 to 0.3 ..	2.0 ..

CARBIDE OF SILICON

Comb. C.	Silicon.	Free C.	Iron.	Alum.
28.0 ..	62.00 ..	7.0 ..	1.50 ..	1.50 ..

F

Aluminium is primarily used as a deoxidiser, and is permitted to be used in various classes of steel. Its oxidation tends to form an insoluble aluminium oxide, added in the form of aluminium or as ferro-aluminium, containing 5%, 10%, and 20%. The amount of aluminium used depends on the particular class of steel for which it is used, and in preference to aluminium for "killing" the oxygen.

Ferro-aluminium is generally supplied in the following form:—

Iron.	Silicon.	Aluminium.
44.15 ..	45.65 ..	9.45 ..

FERRO-ALUMINIUM.

The melting and manufacturing difficulties of aluminium have largely overcome, and it now takes a prominent place in the metallurgy along with nickel, chromium, and manganese as an alloy, having neither distinctive character nor properties of its own, such as chromium, nickel, or chromium-nickel, and nickel-molybdenum, or manganiferous steels.

Nickel.	Manganese.
30 to 50 ..	50 ..

Chromium.
30 ..

Manganese.

Iron.	Nickel.	Silicon.
15.68 ..	30.0 ..	47.2 ..

Nickel.	Chromium.
24.00 ..	7 ..

Phosphorus.	Manganese.
25.0 ..	6 ..

Cobalt.
80 to 85 ..

Silicon.	Chromium.	Iron.
17.17 ..	50.2 ..	28 ..

The information relating to the ferro-phosphorus manufactured in this country is as follows:—

The ferro-phosphorus is manufactured in the following forms:—

The remaining contents as indicated.

OTHER ALLOYS USED IN STEEL

Alloying elements or as Deoxidisers. Several factors, operating together, must be considered to fix an exact amount of Alloy.

powerful deoxidising and strengthening agent in the ferrite, but the use of phosphorus in high-speed and special steels to reduce grain size and increase strength is characteristic of the ordinary steels. It may be considered as a factor in analysis, which may be

Phosphorus. Carbon.
.. 0.45 .. 0.40

titanium, titanium, as ferro-titanium at comparatively little cost, probably its indirect qualities of greater value. Indirectly it has a strong affinity for nitrogen. In the ladle, replacing the manganese, titanium remains in the steel, giving it strength, toughness, and wearing qualities.

and 12%, and is sold by weight per pound of titanium

Ir.	Phosphorus	Manganese.
2	0.04	—

contents range between

of alloy, is as follows :—

Aluminium. Iron.
.. 0.80 .. 74.30

the mechanical properties of the steel. One of the first steels was the introduction of 1.5 to 2.3% of manganese and in high-speed steels,

Silicon.
0.25 to 0.50

Nickel.

Nickel may be said to have been the pioneer among the common alloys now used in steel manufacture. A straight nickel steel has remarkably good mechanical qualities when subjected to heat-treatment, is excellent for casehardening, and its machining qualities take a high place among the alloy steels. This alloy primarily influences the strength and ductility of steel in that the nickel compound, which is dissolved directly in the iron or ferrite. In this sense it is distinct from other elements as chromium and manganese, which unite with and emphasise the character of the carbon component.

During recent years there has been an increasing use of nickel steels in parts that require additional strength and in which a heat-treating process is not practicable, such as plate steel in boiler and bridge work. For casehardening steels the value of nickel has long been recognised. In comparison with carbon steels, corresponding nickel steels show less susceptibility to brittleness due to prolonged heating at the high temperatures often used in carburisation.

This alloying element, as ordinarily issued, is over 99% pure. It is frequently used as a deoxidiser, with other elements, as ferro-nickel, ferro-nickel-chrome, ferro-nickel-silicon, nickel-tungsten, nickel-molybdenum, nickel-chromium, etc.

FERRO-NICKEL.

Ferro-nickel is supplied with 25, 35, 50, or 75% of nickel. The balance of analysis consists of nickel and iron contents being about :—

Carbon.	Silicon.	Sulphur.	Phosphorus.
0.85 ..	0.25 ..	0.015 ..	0.025 ..

FERRO-NICKEL-CHROME.

The improvement in ductility and toughness to carbon steel conferred by nickel can be considerably increased with the addition of chromium. The improvement in strength, surface hardness, and depth-hardening obtained by the influence of chromium. A proper combination of the two alloys will accentuate the density of structure, resulting in greater strength and toughness, and responsiveness to heat-treatment, as well as confer distinctive properties not characteristic of either alloy when used alone.

The analyses of ferro-nickel-chrome approximate between the following :—

Iron.	Nickel.	Chromium.	Carbon.	Other Elements.
29 to 30 ..	17 to 19 ..	51 to 52 ..	0.25 to 0.75 ..	0.10 to 0.20 ..
28 .. 29 ..	17 .. 19 ..	50 .. 51 ..	1.30 .. 1.80 ..	0.10 .. 0.20 ..

Calcium Silicide.

This alloy has a powerful deoxidising influence, and is frequently used in preference to manganese. The main advantage is due to the slag formed. As a result of the oxidation of calcium, the slag is more easily fusible, and is more readily eliminated in the ingot than that formed from the oxidation of aluminium.

Average Analysis.

Calcium.	Silicon.	Iron.	C. Carbon.	Aluminium.	Magnesium.	Sulphur.
26.20 ..	38.40 ..	4.90 ..	0.87 ..	6.25 ..	0.27 ..	0.27 ..

SILICON-ALUMINIUM-MANGANESE.

Silicon.	Aluminium.	Manganese.	Carbon.	Iron.
25.0 ..	15.0 ..	58.0 ..	0.2 to 0.3 ..	2.0 ..

CARBIDE OF SILICON

Comb. C.	Silicon.	Free C.	Iron.	Alum.
28.0 ..	62.00 ..	7.0 ..	1.50 ..	1.50 ..

STEEL MAKING.

operating in a variety of ways,
alloy for a charge.

Ferro-Aluminium.

Aluminium is primarily used as a deoxidising agent, but it is important to define the amount permitted to be used in various classes of steel. This is necessary, because the alumina formed by oxidation tends to form an insoluble slag which is often imprisoned in the ingot. It may be added in the form of aluminium or as ferro-aluminium, which is obtainable with aluminium contents of 5%, 10%, and 20%. The amount of aluminium per ton of steel should be calculated according to the particular class of steel for which it is to be used. Ferro-aluminium-silicide is frequently used in preference to aluminium for "killing" steel.

Ferro-aluminium is generally supplied with aluminium content 5%, 10%, and 20%.

FERRO-ALUMINIUM-SILICIDE.

Iron.	Silicon.	Aluminium.	Carbon.	Sulphur.	Phosphorus.	Mn.	Cu.
44.15 ..	45.65 ..	9.45 ..	0.55 ..	0.010 ..	0.027 ..	trace ..	trace ..

Molybdenum.

The melting and manufacturing difficulties formerly associated with molybdenums have been largely overcome, and it now takes a very distinctive place in structural or engineering alloy-steel-metallurgy along with nickel, chromium, vanadium, and manganese. Molybdenum acts primarily as an alloy, having neither distinctive cleansing nor deoxidising effects. The presence of other alloys, such as chromium, nickel, or chromium-nickel is necessary to realise fully the effect of the molybdenum addition, and nickel-molybdenum or chromium-molybdenum alloys are frequently employed.

NICKEL-MOLYBDENUM.

Nickel.	Molybdenum.	Carbon.	Silicon.
30 to 50 ..	50 to 70 ..	0.5 to 1.0 ..	0.25 to 0.50 ..

CHROMIUM-MOLYBDENUM.

Chromium.	Molybdenum.	Carbon.
30.0 ..	50.0 ..	0.50 ..

Miscellaneous Alloys.

FERRO-NICKEL-SILICON.

Fe.	Ni.	Si.	Al.	Mn.	Ca.	Mg.	P.	Cu.
15.68 ..	30.0 ..	47.2 ..	2.9 ..	0.9 ..	0.15 ..	0.57 ..	0.02 ..	2.58 ..

NICKEL-CHROMIUM.

Nickel.	Chromium.	Carbon.	Silicon.
24.00 ..	72 to 75 ..	1.00 ..	0.25 ..

PHOSPHOR-MANGANESE.

Phosphorus.	Manganese.	Iron.	Carbon.	Silicon.
25.0 ..	65.0 ..	7.0 ..	2.0 ..	1.0 ..

FERRO-COBALT.

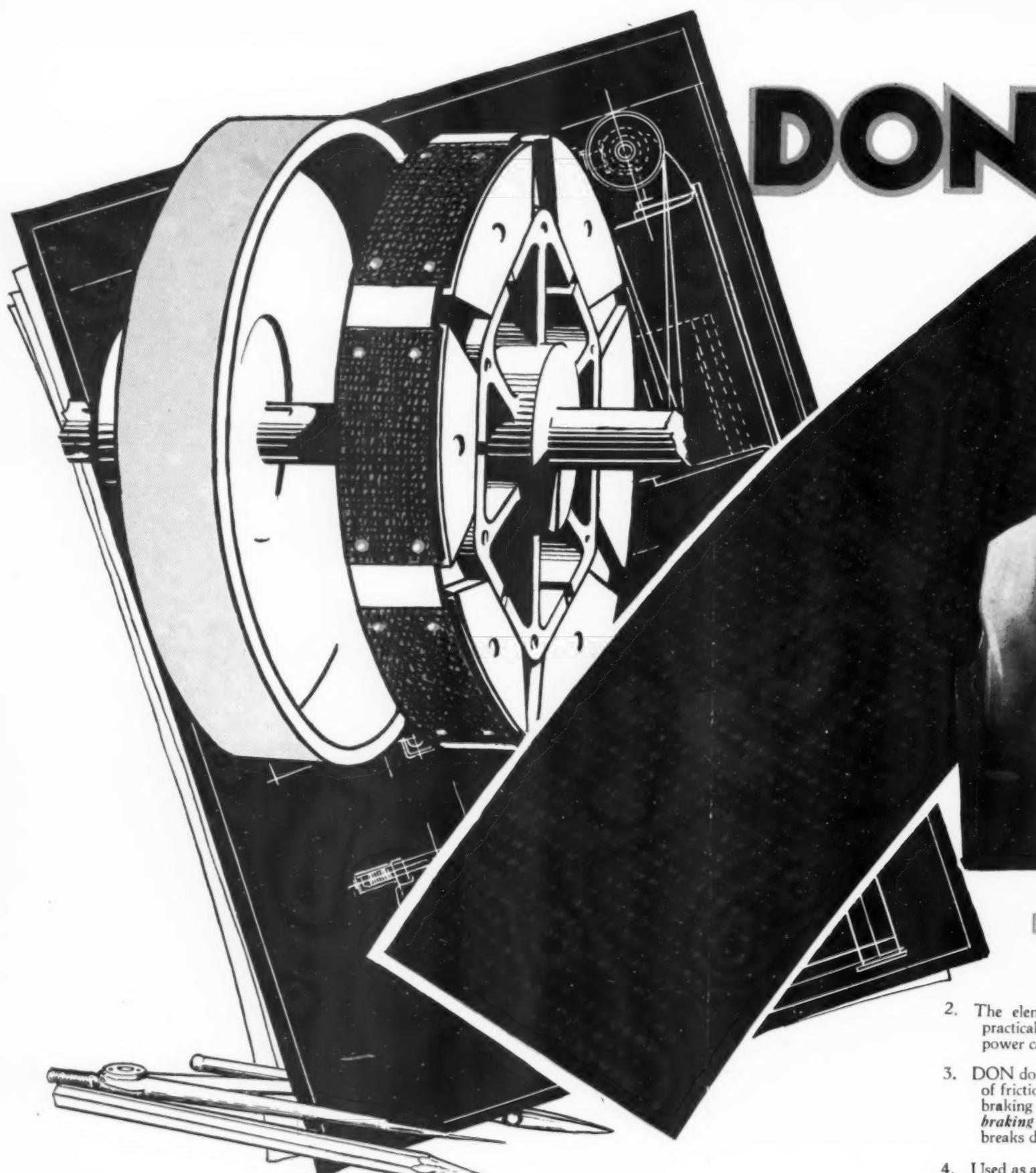
Cobalt.	Nickel.	Sulphur.	Iron.
80 to 85 ..	1 to 2 ..	0.06 ..	Balance ..

SILICON-CHROMIUM.

Si.	Cr.	Fe.	C.	S.	P.	Mn.	Mg.
17.17 ..	50.2 ..	28.2 ..	3.4 ..	0.01 ..	0.03 ..	0.7 ..	0.24 ..

Ferro-Phosphorus.

The information relating to the above alloy, and referred to in the previous chart as the only ferro-phosphorus manufactured in this country by the direct method, was erroneous. It is not manufactured in this country. The analysis should read carbon 0.15%, and the silicon 0.78%, the remaining contents as indicated.



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N FRICITION-LINING AND THE



DON Points for Designers:

1. DON friction-lining is made entirely of pure long asbestos fibre, woven integrally with brass wire.

The elements—Asbestos and Brass wire—now are proved to be practically the only way in which the heat of suddenly arrested power can be controlled safely.

DON does not burn out. Used as brake-lining, the high coefficient of friction which is a unique DON characteristic, gives safe, positive braking with infinitely long life. The heat surge of braking (and all braking is a momentary conversion of power into heat), never breaks down the interwoven metal-wire and asbestos DON structure.

Used as a power transmitter—in clutch form—the grip of DON locks the clutch parts as though the driving and driven members were an integral unit. If clutches are required for mechanisms having slip allowances by adjustable degrees of pressure contact, DON safely will survive the heat so generated during this predetermined slipping period.

SMALL

DON FRICTION-LINING



DON Points for Designers:

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4. Used as a power transmitter—in clutch form—the grip of DON locks the clutch parts as though the driving and driven members were an integral unit. If clutches are required for mechanisms having slip allowances by adjustable degrees of pressure contact, DON safely will survive the heat so generated during this predetermined slipping period.

LINING AND THE DESIGNER.



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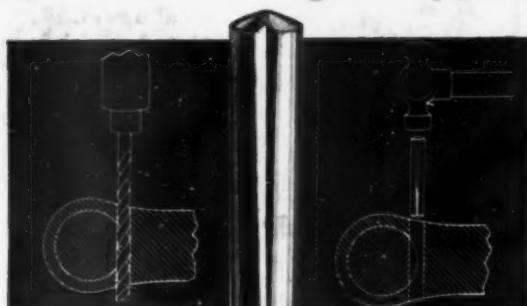
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Composition a

COPPER-TIN ALLOYS.

TRUE bronze consists of copper and tin, although other elements are almost invariably associated to form the wide variety of compositions recognised as bronzes. The influence of tin is greater than zinc in modifying the properties of copper, and in consequence the range is within much lower limits than is the case with the copper-zinc alloys. The colour of copper is more readily influenced by tin, and the red colour quickly disappears as tin is added, being reddish yellow with 5% of tin, through yellow to a greyish white with 30%. The yellow is usually lighter than in the case of a brass, although the surface darkens in contact with the air. A comparatively small percentage of tin with copper gives an alloy having considerable strength and hardness, but if increased beyond 20% a considerable reduction in strength occurs.

The ductility of these alloys begins to fall at about 5% tin, and is entirely gone with 25% tin, to recommence at the other end of the scale, between 80 and 90% of tin. The lack of ductility between 20 and 80% of tin is very marked. When the tin content exceeds 5% the alloy does not solidify as a whole; two constituents are formed which solidify at different temperatures. Above 10%, and within 20% of tin, the alloy becomes more complex, with three freezing stages, while with 40% of tin there are four distinct freezing points. Due to the different temperatures at which varying constituents solidify, the copper-tin alloys are naturally liable to segregate, which increases the difficulty in producing a homogeneous bronze alloy. Obviously, the structure of copper-tin alloys is influenced by cooling—the slower they are allowed to cool when the tin contents exceeds 5%, the greater the amount of segregation. To secure density and uniformity, solidification should be effected as rapidly as possible. There are few copper-tin alloys in commercial use, and these usually require the addition of another element to act as a deoxidiser.

Name of Alloy.	Copper.	Tin.	Other Additions in Small Quantities.
Speculum metal	70—65	30—35	Zinc and arsenic
Bell metal	80—75	20—25	Lead, iron, and zinc
Gunmetal	92—88	8—12	Zinc
Coin bronze	90—96	10—4	Zinc

Speculum metal was formerly used for reflectors. It is a hard, white metal, which takes a brilliant polish. It is difficult to produce a sound casting from this alloy. Bell metal is hard and brittle. An 80-20 alloy is normal, but higher tin increases the quality of resonancy, which is a characteristic of this alloy, and which is, in a measure, dependent upon the shape of the bell. Gunmetal is a tough and strong alloy, capable of resisting forces resulting from shock. Coin bronze is an alloy that is required to be tough, and should be within the range of ductile alloys, because coins or medals are invariably struck in a die.

OTHER ALLOYING ELEMENTS.

The more useful of the bronzes invariably contain some other element or elements either to produce more homogeneous alloys or to facilitate working. Probably the more common addition is zinc. In the alloys of copper and tin the oxide formed is liable to become entangled in the metal, breaking the continuity of the structure and reducing its strength. The addition of zinc, the oxide of which more readily rises, is a means of overcoming the difficulty and the standard gunmetal, which is regarded as the basis for good quality bronze, contains up to 2% of zinc with 88-10 copper-tin.

Phosphorus, in the form of phosphor-tin or phosphor-copper, is frequently added to copper-tin alloys for two reasons, the first being purely as a deoxidising medium, and in which the alloy will only contain traces of phosphorus, the extent of the cleansing being indicated by the complete removal of the phosphorus. The second reason for its use is in the definite formation of a phosphor bronze, in which an appreciable percentage of phosphorus remains in the alloy to toughen it.

Manganese is sometimes used instead of phosphorus as a deoxidising agent. It has the additional effect of reducing the brittleness of a copper-zinc alloy, and can be used in excess without impairing the quality.

Lead is included in many bronzes because it improves machining qualities and facilitates manufacture. It is insoluble in the solutions formed by copper and tin, and in consequence care is necessary to hasten the solidification of bronzes in which it is included. Within low limits it makes no appreciable difference to the strength of an alloy. It is used for bearing bronzes to a varying degree up to as much as 15%.

Silicon is an improved mechan bronze.

Copper.
88
86
84
87—89
85—89
82
88
89
85
90
89
75
90—78

Copper.
88
84·5
88·4
90—91
89—90
88

Copper.
75—76

Copper.
97—98

Copper.
80
85
88

and Uses of Some Bronzes.

on is an excellent deoxidiser, and materially assists the production of sound casting with mechanical qualities. It is also effective in improving corrosive resistant qualities as of

SOME COMMERCIAL BRONZES.

Copper.	Tin.	Zinc.	Lead.	Purpose.
88	10	2		Steam valves and important castings
86	12	2		Hydraulic pump metal
84	9	6	1	General work of good quality
87-89	9-11	1-3	0.2 Max.	Valves and important castings
85-89	9-11	1.5-2.5	0.8 Max.	Durable castings
82	8	4	6	Shaft and pump liners
88	8	2	2	Small valves subjected to high pressure
89	5	3	3	Valves and steam fittings
85	5	5	5	Pump bodies, steam fittings and bearing
90	6.5	2	1.5	Steam fittings and automobile bearings
80	6	8	6	Valve chests, spindle bushes, etc.
75	5	12	8	Neck bushes and bearings
90-78	2-4	10-18	1-4	Statuary bronze

SOME PHOSPHOR BRONZES

Copper.	Tin.	Zinc.	Lead.	Phosphorus.	Purpose.
88	10.5	1		0.5	Gears and bearings
84.5	10		5	0.5	Locomotive slide valves
88.4	11	0.1 Max.	0.2	0.3	Bearing bronzes for heavy work.
90-91	9-8			1.0	Gears
9-90	6-8	1	0.2	0.3	Bearings
88	11			0.3	Gears

MANGANESE BRONZE

Copper.	Tin.	Manganese	Purpose.
5-76	6-5	16-17	Castings required to resist corrosion

SILICON BRONZE

Copper.	Tin.	Zinc.	Silicon.	Purpose.
7-98	1-2	1-1.5	0.05-0.07	Castings for electrical work. Resistant to corrosion

BRONZES FOR BRIDGE WORK.

Copper.	Tin.	Zinc.	Lead.	Phosphorus.	Purpose.
80	20			To 1%	Castings in contact with hard steel subjected to pressure above 1,500 lb. per sq. in.
85	15		—	To 1%	Castings in contact with mild steel at pressures under 1,500 lb. per sq. in.
80	10	2	10	To 1% To 0.25%	Ordinary bearings Gears, worm wheels, etc.
88	10				

PREPARATION

It is not economical to make use of scrap which is wholly of returns from machine shop or which composition will be known. It should, of course, be carefully selected. Outside scrap should be carefully selected as its composition is known. It is frequently practicable to take a sample from each cast in order to define the composition when making up a subsequent charge, by this method. Generally, two or three compositions are made up of tin to alloy with a given amount of scrap, which will contain a given amount of copper, which is graded into, say, three compositions as follows:

	Copper
A	90
B	82
C	88

A charge of 50% scrap from one of the three compositions and the remainder being made up from virgin metal, the composition of the charge could be:—

50% scrap A.....
43% virgin copper
5% tin
2% zinc
100%.....

A small allowance could be made for the scrap, which stipulates a maximum of 2%, this allowance being within the limit.

In preparing a charge for, say, general use, the following could be:—

50% scrap B.....
44% virgin copper
1% tin
3.5% zinc (allowance for 10% loss)
2% lead

Invariably, a total loss of approximately 10% is experienced.

Many types of furnaces are used for melting the metal, but control of the heating element, but control of the furnace to prevent oxidation is the ideal to be aimed at, as good melting is the result. The copper and scrap are melted under controlled conditions. Thorough stirring is essential. The melting temperatures will give some idea of the melting point.

Copper, %
Tin, %
Melting point, °C.

Overheating should be avoided, particularly in the early stages of the melting process, as this will affect the character of the metal. A temperature of 1,000° C. is all that is necessary to reduce the time required for the metal to be cast without deoxidising.

Composition and Uses of S.

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86	12	2	—	Hydraulic pump metal
84	9	6	1	General work of good quality
87-89	9-11	1-3	0.2 Max.	Valves and important castings
85-89	9-11	1.5-2.5	0.8 Max.	Durable castings
82	8	4	6	Shaft and pump liners
88	8	2	2	Small valves subjected to high pressure
89	5	3	3	Valves and steam fittings
85	5	5	5	Pump bodies, steam fittings and bearing
90	6.5	2	1.5	Steam fittings and automobile bearing
80	6	8	6	Valve chests, spindle bushes, etc.
75	5	12	8	Neck bushes and bearings
90-78	2-4	10-18	1-4	Statuary bronze

SOME PHOSPHOR BRONZES

Copper.	Tin.	Zinc.	Lead.	Phosphorus.	Purpose.
88	10.5	1	—	0.5	Gears and bearings
84.5	10	—	5	0.5	Locomotive slide valves
88.4	11	0.1 Max.	0.2	0.3	Bearing bronzes for heavy work.
90-91	9-8	—	—	1.0	Gears
89-90	6-8	1	0.2	0.3	Bearings
88	11	—	—	0.3	Gears

MANGANESE BRONZE.

Copper.	Tin.	Manganese	Purpose.
75-76	6-5	16-17	Castings required to resist corrosion

SILICON BRONZE.

Copper.	Tin.	Zinc.	Silicon.	Purpose.
97-98	1-2	1-1.5	0.05-0.07	Castings for electrical work. Resistant to corrosion

BRONZES FOR BRIDGE WORK.

Copper.	Tin.	Zinc.	Lead.	Phosphorus.	Purpose.
80	20	—	—	To 1%	Castings in contact with ha
85	15	—	—	To 1%	steel subjected to pressure above 1,500 lb. per sq. in.
80	10	—	10	To 1%	Castings in contact with m
88	10	2	—	To 0.25%	steel at pressures under 1,500 lb. per sq. in.
					Ordinary bearings
					Gears, worm wheels, etc.

Some Bronzes.

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els, etc.

PREPARATION OF MIXTURES.

It is not economical to make use of virgin metals entirely, and scrap must be used. When this is wholly of returns from machine shop or foundry, it can generally be sorted out accurately, as its composition will be known. It should, of course, be separated and stored according to composition. Outside scrap should be carefully selected, and should only be used in important work when its composition is known. It is frequently profitable to melt down scrap and run it into ingots, analysing a sample from each cast in order to define the composition. This gives fairly reliable information when making up a subsequent charge, but it is better to separate a firm's own from outside scrap. Generally, two or three compositions predominate, and it is good practice to prepare the amount of tin to alloy with a given amount of scrap and virgin copper to make up a charge. Small ingot moulds, which will contain a given amount of tin, can be profitably employed. Thus, if the scrap is graded into, say, three compositions approximating to those in table as A, B, and C.

	Copper	Tin.	Zinc.	Lead.	Phosphorus.
A	90	10			
B	82	8	4	6	
C	88	10.5	1		0.5

A charge of 50% scrap from one of the grades of scrap will fulfil average requirements, the remainder being made up from virgin metals. In preparing a charge for an 88-10-2 alloy, the charge could be:—

50% scrap A.....	£45	5	0
43% virgin copper	43	0	0
5% tin	0	5	0
2% zinc	0	0	2
100%.....			£88 10 2

A small allowance could be made for loss of zinc, but since Admiralty bronze specification stipulates a maximum of 2%, this allowance could be omitted and the resulting allowance would be within the limit.

In preparing a charge for, say, general castings, consisting of 85 Cu, 5 Sn, 5 Zn, 5 Pb, the charge could be:—

	Copper.	Tin.	Zinc.	Lead.
50% scrap B.....	41	4	2	3
44% virgin copper	44			
1% tin		1		
3.5% zinc (allowance for 10% loss)			3.5	
2% lead				2
	85	5	5.5	5

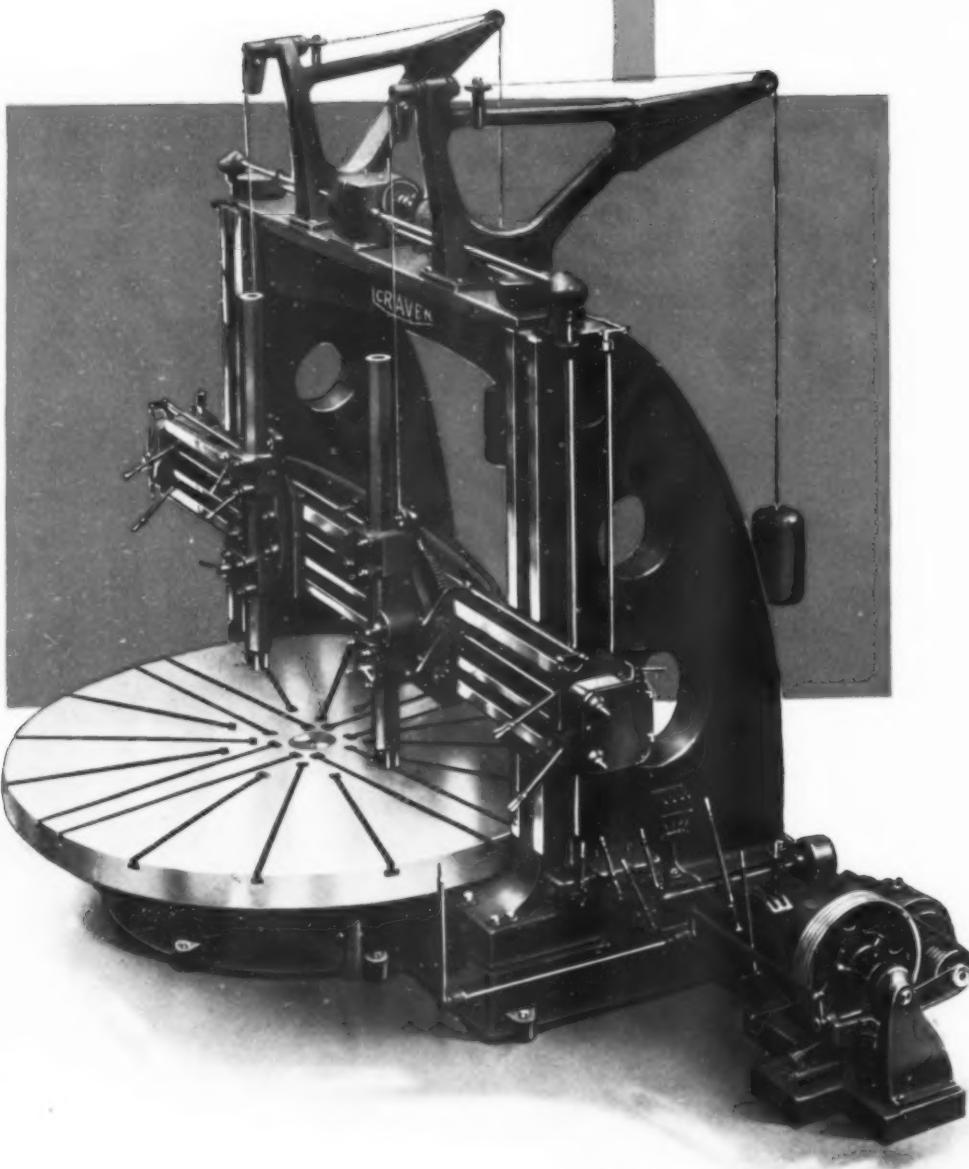
Invariably, a total loss of approximately 3% results from oxidation, dirt, and volatilisation.

MELTING.

Many types of furnaces are used for melting these alloys, and coke, oil, gas or electricity may provide the heating element, but control of temperature with conditions favouring neither reducing nor oxidising is the ideal to be aimed at, and any type of furnace that fulfils these conditions facilitates good melting. As a rule, however, it is necessary to protect the surface of the metal with charcoal. The copper and scrap are melted under charcoal, and the metals of lower fusing temperatures added. Thorough stirring is essential. The melting point of the copper-tin alloys falls progressively, and the following temperatures will give some indication of the melting points for other alloys:—

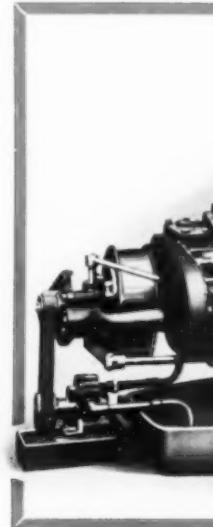
Copper, %	100	85	75	0
Tin, %	0	15	25	100
Melting point, °C.	1100	870	790	230

Overheating should be avoided, particularly with the phosphor bronzes, as they are very searching in their character. A temperature just high enough to ensure complete filling of a mould is all that is necessary to reduce the time during which segregation can take place. As soon as the metal is ready it should be cast without delay, and moulds should be filled as rapidly as possible.



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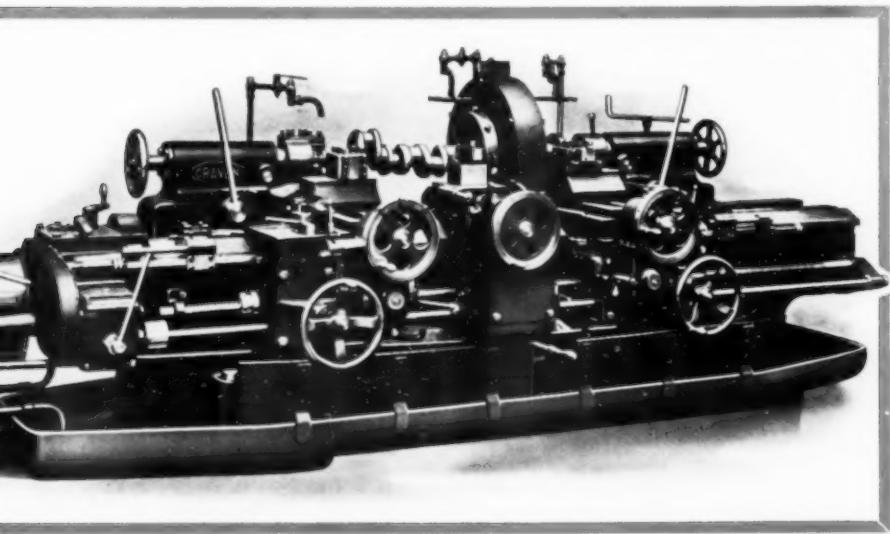
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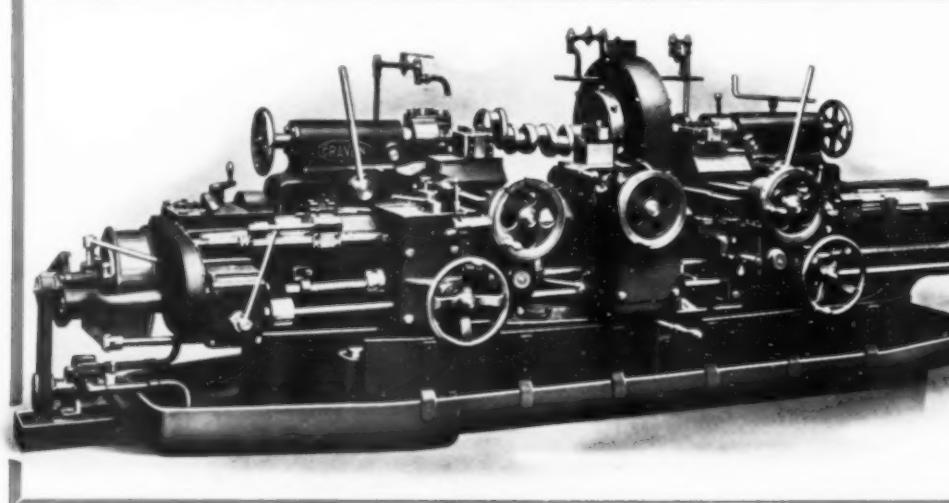
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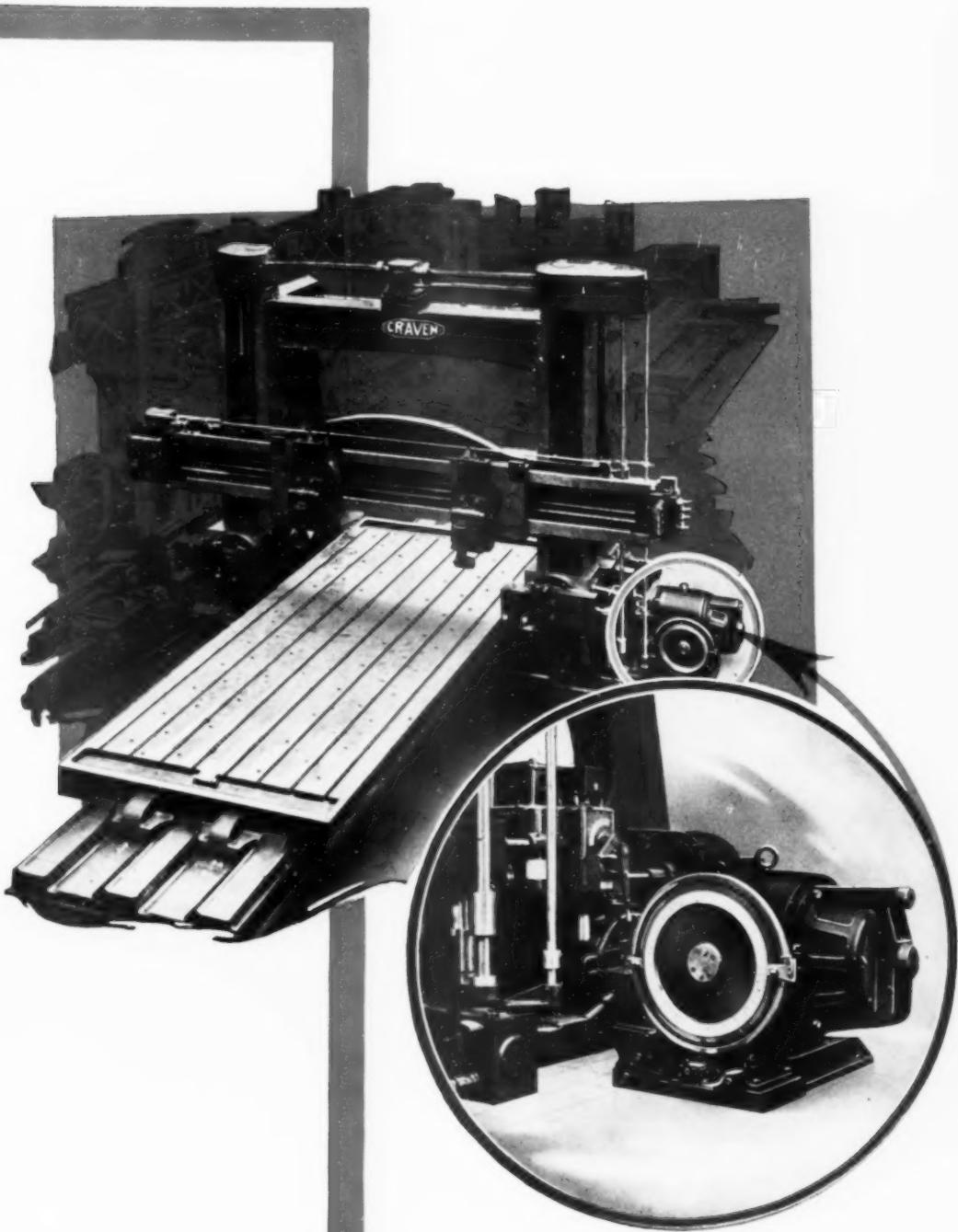


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casings and
crankshafts.

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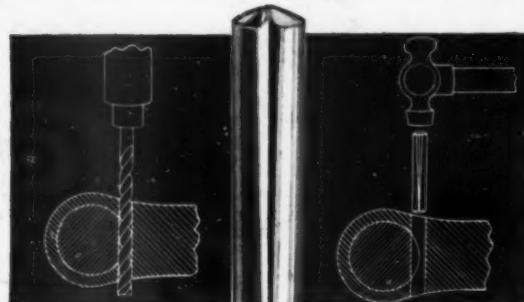
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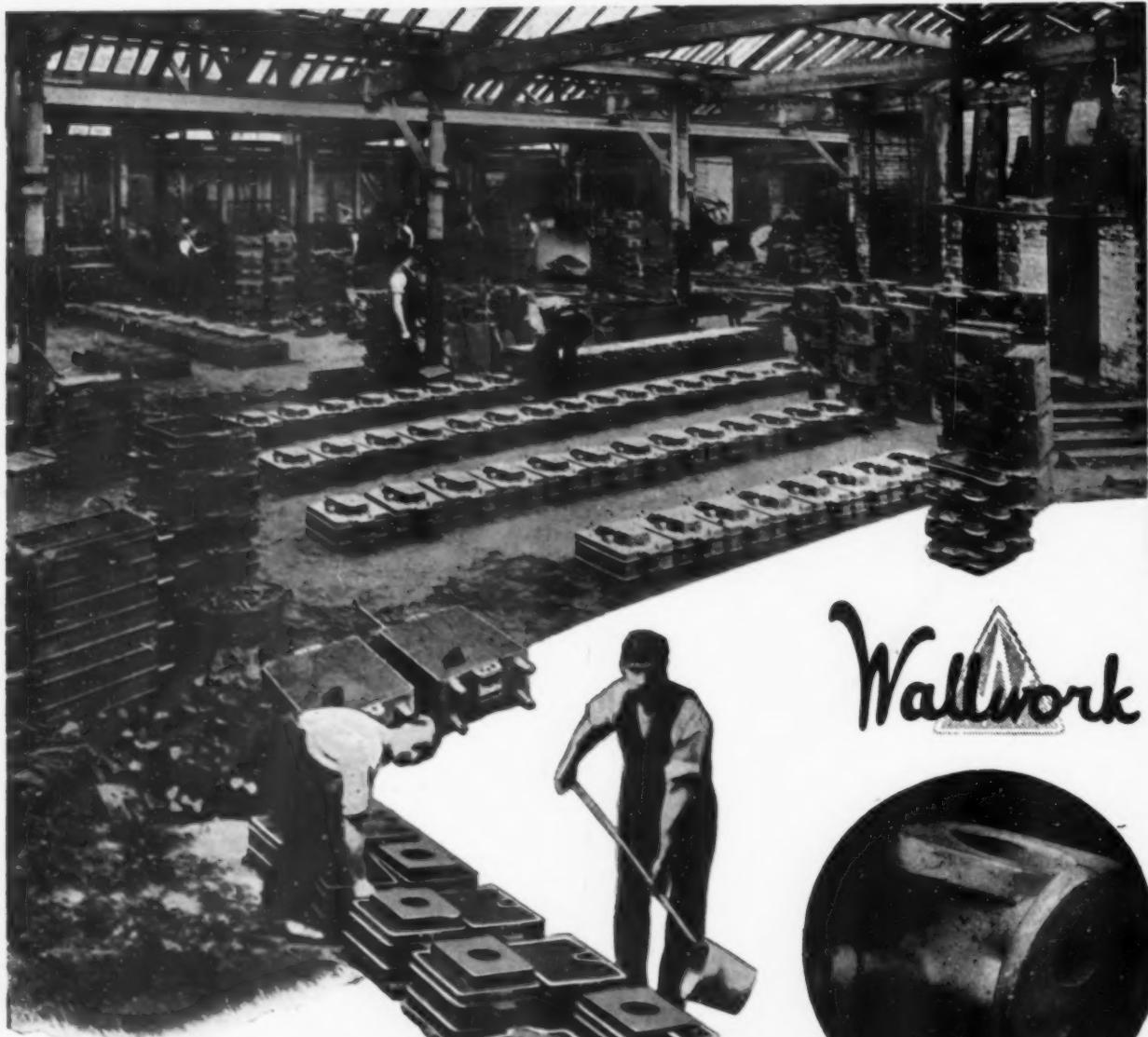
GS. 2. With notches in ungrooved portion.



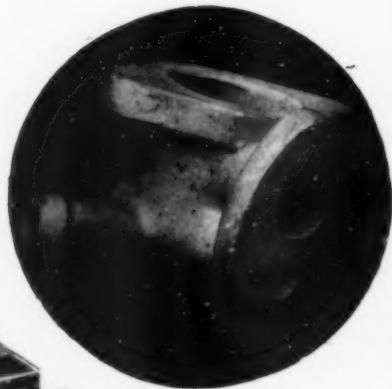
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Alloying Cast Iron

ENGINEERS recognise that cast iron possesses valuable properties which render it superior in many applications to other more refined and expensive alloys. The ease of melting and casting, its good machinability and wearing qualities, are but a few of its characteristics, and it is not surprising that there should be a constant demand for improved qualities to meet the increased service necessitated by engineering progress. It is generally recognised that the progressive tendency requires castings of no higher weight, but so constituted that they are capable of resisting the increased intensity of the working conditions in which they are used.

The results of much research indicate the value of certain alloying elements, and the work of many investigators has shown the advantages of the inclusion of small percentages of nickel in cast iron. The value of a chromium addition has also been demonstrated by research work, and investigations have shown the possibilities of improving cast iron for particular work by alloying it with chromium.

PRINCIPAL EFFECTS OF NICKEL.

Suitable additions of nickel to cast iron have the effect of refining the grain, particularly in the heavier sections, in which silicon tends to open the structure, and it lowers machining costs by reducing chill and hard spots. It also maintains a high combined carbon in the composition, which tends to retain its strength and hardness in thicker sections. It can be used to secure uniformity of hardness in castings of varying sections.

Nickel promotes the formation of graphite, but of a much finer grain. It is desirable to reduce the silicon content to secure grain refinement, but frequently the severe chilling resulting from silicon reduction renders it undesirable. Reducing the silicon and adding nickel enables the grain refinement to be maintained and reduces the possibility of chilling. The general improvement in soundness resulting from the inclusion contributes to increased strength of the iron. It must be understood that the amount of nickel and silicon requires to be regulated to produce a desired effect.

The improvements in cast iron having suitable additions of nickel may briefly be noted as: Reduction of chill, which lowers machining costs; increase of hardness without interfering with machinability; uniformity of hardness in heavy and light sections; increase of strength and resistance to wear.

PRINCIPAL EFFECTS OF CHROMIUM.

The addition of small percentages of chromium has very little influence on the corrosion-resisting qualities of the cast iron. The reduction is more noticeable with sea water, but with weak acids and ammonium chloride little advantage results. In quantities up to 0.90% chromium increases the stability of the combined carbon in grey cast iron at temperatures up to 550°C. Its inclusion increases strength and hardness at ordinary as well as elevated temperatures, and gives better heat-resisting irons; machining, however, presents a difficulty.

The use of both alloying elements together with the object of obtaining the advantages of each, and the value of one element to counteract the adverse effects of the other has been experimented upon, and compositions are now used in practice.

SUGGESTED COMPOSITIONS FOR HIGH-DUTY CASTINGS. MOTOR CYLINDERS.

For castings in which increased hardness and wearing properties, together with good machining qualities, are governing factors, as in the case of motor cylinders, the silicon should be reduced by 0.5%, and 1 to 2% nickel added. If the silicon cannot be reduced conveniently, add from 0.3 to 0.5% chromium and 1% nickel.

Total Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Nickel.	Chromium.
3.20	1.25	0.10	0.70	0.80	1.5	0.4
3.20	1.75	0.10	0.70	0.80	1.0	0.4

Pistons
work add fre
iron must be

To
Small
Sections
Large
Sections

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if for large p

Total Ca

3.5

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Total Ca

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HY

High-wea
and nickel-ch

Medium ..
Heavy ..

Light ..
Heavy ..

Light ..
Heavy ..

Iron with Nickel and Chromium

PISTONS AND PISTON RINGS.

Pistons and piston rings require good wearing and machinability qualities. For small section add from 0.25 to 0.75% nickel to reduce chill and refine the grain. If a relatively high silicon must be used, add both nickel and chromium.

Total Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Nickel.	Chromium.
1.0	3.5	1.75	0.05	0.60	0.70	0.50
1.0	3.5	2.0	0.05	0.60	0.70	0.75
1.0	3.25	1.5	0.06	0.50	0.80	1.0
1.0	3.25	1.75	0.06	0.50	0.80	1.0

CASTING

The refining of the grain is of withstanding high pressures, nickel may be added, and the reduction of silicon is not con-

Total Carbon.	Silicon.
Light	3.25
Heavy	2.85

CUT GEARS AND PINIONS.

High strength and good wearing qualities, with absence of porosity, such as are necessary for gears and pinions, can be obtained by the addition of 1 to 3% of nickel to a low silicon iron, or, for large gears, nickel and chromium in the ratio of 3 to 1.

Total Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Nickel.	Chromium.
3.5	1.75	0.08	0.70	0.60	2.0	—
3.25	1.5	0.10	0.50	1.0	1.5	0.5

METHODS OF

The alloys may be charged claimed that there is no appreciable loss of chromium from this casting, the work being cast requires an addition is more suitable for with the general work of the

ADDI

For this purpose ordinary be used, or nickel-silicon in the charged on the pig iron at

Chromium should be charged in too fine a form to charge to hold the alloy in a conven-

Where it is possible, high to form special alloying pigs can be charged into the cup, particularly suitable in those engineering.

ADDI

The melting point of a of cast iron, renders it a suitable may be used, the nickel-silicon shot, and is calculated on a chrome graded to pass a 10% carbon grade can be converted should be mixed, allowance

There are many methods convenient way is to feed the pieces forces them into the trough to meet the stream directed to join the stream action of the stream will for and facilitating its complete commencing to add the nickel the bottom of the ladle and

HYDRAULIC CYLINDERS.

Total Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Nickel.	Chromium.
1.0	3.25	1.5	0.05	0.50	0.80	1.5
1.0	3.25	2.0	0.04	0.20	0.60	1.5

STEAM CYLINDERS.

Total Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Nickel.	Chromium.
1.0	3.5	1.75	0.08	0.50	0.60	1.5
1.0	3.5	1.0	0.10	0.30	1.0	1.75

GAS ENGINE CYLINDERS.

Total Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Nickel.	Chromium.
1.0	3.25	1.75	0.08	0.40	0.70	1.5
1.0	3.25	1.0	0.10	0.20	0.90	1.75

Alloying Cast Iron with Nickel

possesses valuable properties which render it superior to refined and expensive alloys. The ease of melting and wearing qualities, are but a few of its characteristics; there should be a constant demand for improved qualities by engineering progress. It is generally recognised that castings of no higher weight, but so constituted that they possess the necessary qualities of the working conditions in which they are used, the value of certain alloying elements, and the work of researches of the inclusion of small percentages of nickel in cast iron has also been demonstrated by research work, and investigation of the use of nickel for particular work by alloying it with

EFFECTS OF NICKEL.

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EFFECTS OF CHROMIUM.

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either with the object of obtaining the advantages of each, or the adverse effects of the other has been experimented upon,

RECOMMENDATIONS FOR HIGH-DUTY CASTINGS.

and wearing properties, together with good machining qualities of motor cylinders, the silicon should be reduced by 0.3 to 0.4% and cannot be reduced conveniently, add from 0.3 to

Phosphorus. Manganese. Nickel. Chromium.

0.70	...	0.80	...	1.5	...	—
0.70	...	0.80	...	1.0	...	0.4

PISTONS AND PISTON RINGS.

Pistons and piston rings require good wearing and machinability qualities. Research work add from 0.25 to 0.75% nickel to reduce chill and refine the grain. If a rough iron must be used, add both nickel and chromium.

	Total Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Nickel.					
Small Sections	{ 3.5	...	1.75	...	0.05	...	0.60	...	0.70	...	0.0
Large Sections	{ 3.5	...	2.0	...	0.05	...	0.60	...	0.70	...	0.0
	{ 3.25	...	1.5	...	0.06	...	0.50	...	0.80	...	1.0
	{ 3.25	...	1.75	...	0.06	...	0.50	...	0.80	...	1.0

CUT GEARS AND PINIONS.

High strength and good wearing qualities, with absence of porosity, such as can be obtained by the addition of 1 to 3% of nickel to a rough iron, for large gears, nickel and chromium in the ratio of 3 to 1.

Total Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Nickel.					
3.5	...	1.75	...	0.08	...	0.70	...	0.60	...	2.0
3.25	...	1.5	...	0.10	...	0.50	...	1.0	...	1.5

HEAT-RESISTING CASTINGS.

For hard and tough heat-resisting iron, fine grain with hard but machinable qualities.

Total Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Nickel.					
3.25	...	1.5	...	0.04	...	0.20	...	0.60	...	1.5
3.25	...	2.0	...	0.04	...	0.20	...	0.60	...	1.5

HYDRAULIC, STEAM AND GAS ENGINE CYLINDERS.

High-wearing properties, combined with close, dense iron, are required for cylinders, and nickel-chromium addition can be profitably used according to the silicon content.

	HYDRAULIC CYLINDERS.				
	Total Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
Medium	3.25	...	1.5	...	0.05
Heavy	2.85	...	1.0	...	0.08

	STEAM CYLINDERS.				
	Light	3.5	...	1.75	...
Light	...	3.5	...	1.75	...
Heavy	...	3.5	...	1.0	...

	GAS ENGINE CYLINDERS.				
	Light	3.25	...	1.75	...
Light	...	3.25	...	1.75	...
Heavy	...	2.85	...	1.0	...

Nickel and Chromium.

S.

qualities. For small section If a relatively high silicon

	Nickel.	Chromium.
..	0.50	..
..	0.75	..
..	1.0	..
..	1.0	..

y, such as are necessary for Nickel to a low silicon iron, or,

Nickel.	Chromium.
2.0	..
1.5	..

chirable surface is required.

Nickel.	Chromium.
1.5	..
1.5	..

CYLINDERS.

red for cylinders, and nickel silicon content of the iron.

	Nickel.	Chromium.
..	1.5	..
..	1.5	..

..	1.5	..	—
..	1.75	..	0.4

..	1.5	..	—
..	1.75	..	0.5

CASTINGS TO RESIST HIGH PRESSURE.

The refining of the grain resulting from suitable additions of nickel makes an alloy iron capable of withstanding high pressures. Thus, for valves and other fittings required to resist high pressure, nickel may be added, and the usual silicon contents reduced or nickel and chromium added if a reduction of silicon is not convenient.

	Total Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Nickel.	Chromium.
Light	..	3.25	..	1.5	..	0.07	..
Heavy	..	2.85	..	1.0	..	0.09	..

METHODS OF CHARGING NICKEL AND CHROMIUM.

The alloys may be charged in the cupola or added as the molten metal enters the ladle. It is claimed that there is no appreciable loss of nickel by oxidation, but it is advisable to allow for slight loss of chromium from this cause. Charging the alloys in the cupola is recommended when all the work being cast requires an alloy iron, as this method gives a more uniform composition. A ladle addition is more suitable for individual casts, allowing special alloy inclusions without interfering with the general work of the foundry.

ADDING DIRECT TO THE CUPOLA.

For this purpose ordinary commercial 99% pure nickel in the form of 5 lb. or 25 lb. pigs may be used, or nickel-silicon in the form of small ingots is available for the purpose. These should be charged on the pig iron and under scrap, and should be placed about the centre of the charge.

Chromium should be charged in a similar way to lump ferro-chrome. Should the ferro-chrome be in too fine a form to charge in this way, some kind of binder, like plaster of Paris, should be used to hold the alloy in a convenient mass and protect it from oxidation.

Where it is possible, high nickel and chromium compositions can be melted in an electric furnace to form special alloying pigs possessing a high percentage of nickel or nickel-chromium, and these can be charged into the cupola more conveniently with low oxidation losses. This method is particularly suitable in those foundries developing nickel-chromium cast irons for use in chemical engineering.

ADDING TO METAL IN THE LADLE.

The melting point of a nickel-silicon alloy (1,260° C.), which corresponds very nearly to that of cast iron, renders it a suitable medium for giving the nickel inclusion required; while pure nickel may be used, the nickel-silicon ensures complete and ready solution. It is obtainable in the form of shot, and is calculated on a nickel content basis of 92%. Chromium may be added as crushed ferro-chrome graded to pass a 10-mesh sieve, and all dust removed by using a 50-mesh sieve. A medium carbon grade can be conveniently crushed. The relative amounts of ferro-chrome and nickel shot should be mixed, allowance being made for loss.

There are many methods of adding the alloying elements to the metal in the ladle. A convenient way is to feed them into the stream of metal as it leaves the cupola. The impact of the pieces forces them into the metal, and the action of the stream provides thorough agitation, which assists complete solution. Another method consists in pouring the alloying elements down a metal trough to meet the stream of metal as it leaves the cupola spout to enter the ladle, or it may be directed to join the stream of metal as it strikes the surface of the iron in the ladle. The churning action of the stream will force the nickel and ferro-chrome under the surface, giving a stirring action and facilitating its complete solution. The ladle should have an amount of molten metal in it before commencing to add the nickel and ferro-chrome, and it is not satisfactory to place the elements at the bottom of the ladle and tap the metal from the cupola on them.

Views of Reinforced Concrete Retort
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heat of combustion is
wasted by careless handling
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the problem of fuel economy, and expressively
state that our range of furnaces, covers
the entire field of heating and heat-treatment
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We build every type of
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and Lead Pot.

A few typical Wincott
furnaces are shown here.

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price!"*

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less handling and burning.
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plore tackled the problem of fuel
expressed real savings in a
series, covering the melting, re-
heat-treatment of iron, steel
and metals.

type of equipment from the
furnace down to the simple

Wincott Furnaces are shown

Each of them is working in a different but
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sensible use of fuel, and to give us an opportunity
of studying your furnace problems.

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build up to
specification,
down to a
science!"

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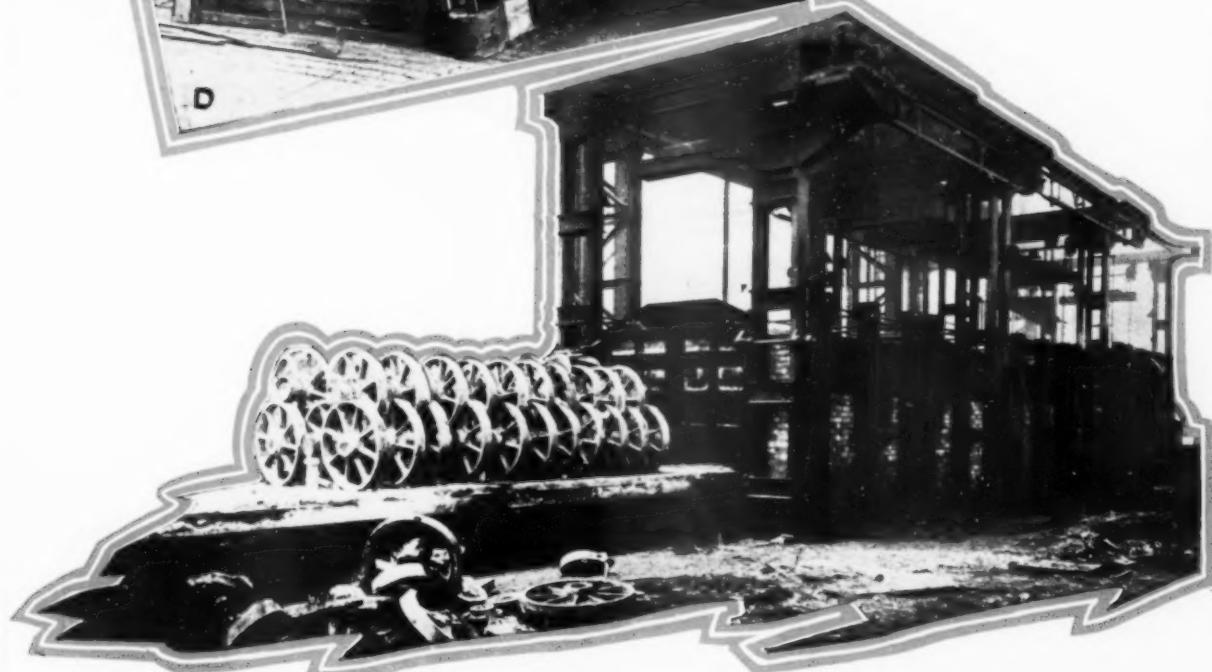
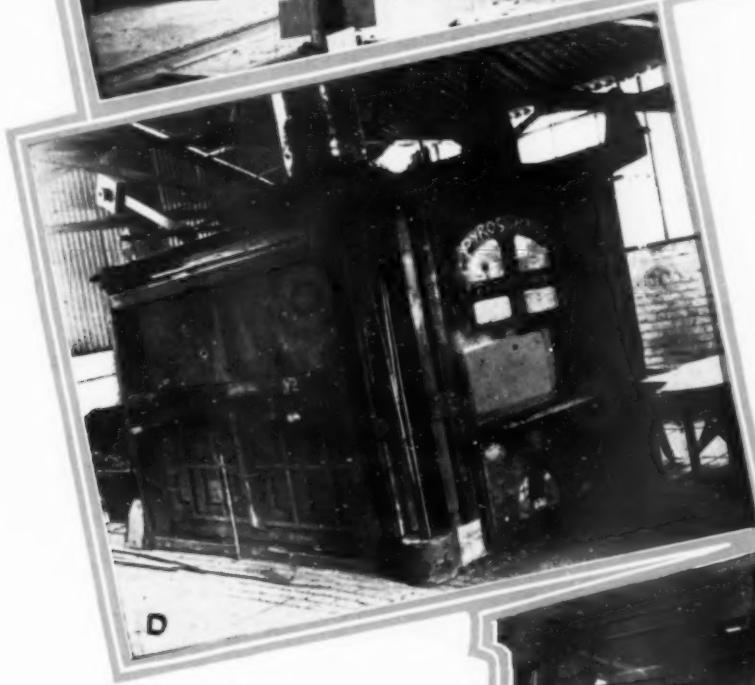
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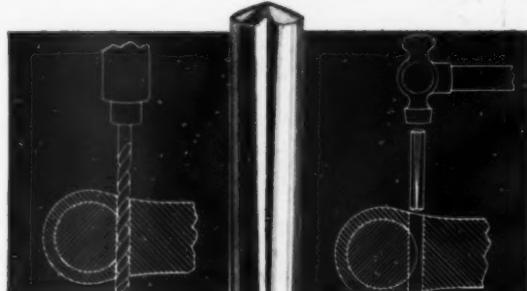
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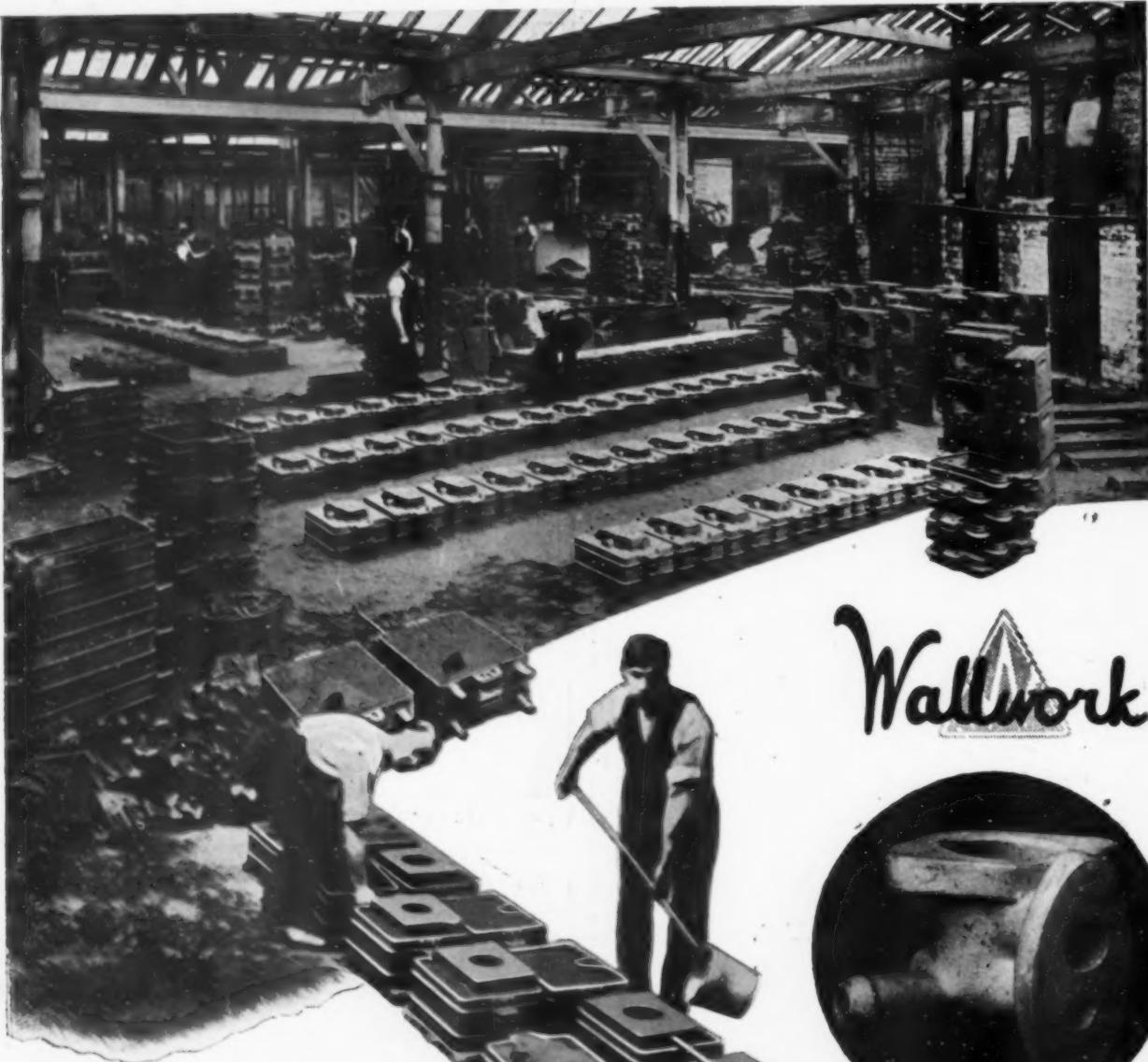
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Grooves extend half length

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Notes on The field for the use of High-Manganese Steel has

HISTORICAL.

ANY investigators experimented with manganese before Sir Robt. Hadfield finally produced the alloy now known throughout the world as Hadfield steel, or more commonly as manganese steel. Probably the first indication of the possibilities of this steel was experienced by Rinman, who in 1774 observed that by fusing equal parts of grey pig iron and manganese oxide the white brittle metal obtained was not attracted by a magnet. Many years later, about the year 1830, Mushet experimented with alloys containing manganese. He used manganese oxide, iron oxide, and cast iron, fusing them with charcoal and using a fluxing agent. He noted the non-magnetic properties of the resulting alloy, but, evidently the carbon content was too high to give the characteristics now associated with manganese steel. Much experimental work was carried out by German research workers, in which various additions of manganese were made, and the results of the subsequent investigations apparently indicated that steels containing much over 1·0% of manganese were brittle. Reports which were prepared about 1875 included an alloy containing 11·0% of manganese, but the carbon content was high—2·42%—and the steel was reported to be brittle. In spite of these discouraging reports regarding manganese alloys, Sir Robert A. Hadfield carried out further investigations, which resulted in the production of a steel which not only made him famous, but revolutionised steel-making. Considerable research work has been involved in determining the proper combination of carbon and manganese, as a result of which the commercial range has greatly widened, and the scope of these manganese steels has been increased.

COMPOSITION.

Manganese steel is similar in analysis to ordinary converter steel, except that the carbon and manganese contents are higher. Its composition is somewhat variable, and approximates to the following analysis:—

C. Mn. Si. S. P.
1.0 to 1.4 .. 10.0 to 14.5 .. 0.3 to 1.0 .. 1.0 to 0.01 .. 0.04 to 0.10

Most commercial manganese steels have about 11 to 12% manganese, with about 1.0 to 1.2% carbon. The ratio of carbon to manganese is generally maintained to approximately 1 to 10.

PHYSICAL CHARACTERISTICS.

The outstanding feature of these steels is their resistance to abrasion rather than in any particularly high static or fatigue strength, and these wear-resisting qualities are not due to its hardness, but to its toughness, which is due to its great molecular cohesion, causing the particles to flow rather than to tear off. When subjected to the Brinell test, it shows a hardness varying between 170 and 200.

The tensile strength varies between 40 and 50 tons per square inch.

Elastic limit about 22 tons per square inch.

Elongation in 2 in., about 33%

Reduction in area about 35%

Specific heat ranges from 0.145 to 0.2 up to 1300°C.

Heat conductivity about a third of low carbon steels between normal temperatures and 600°C .

Electrical resistance approximately 3·4 times the resistance of ordinary Bessemer steel, and between 100° and 600° C. the resistance is claimed to remain practically constant.

Contraction is high, amounting to $\frac{5}{16}$ in. per foot.

Contraction is high, amounting to $\frac{5}{16}$ in. per foot.

Owing to the heat produced, the temperature will control the rate of release as soon as the capsule is out. Those of unusual size and placed in a heating

Originally Hade had reduced the metal to a convex shape, subsequently adding to it. The difficulties encountered in this work were great, as scrap without the alloy was not available, and the metal had to be used to a certain extent. He had, however, a method of retaining the alloy, which was the Swedish practice of "dipping" the metal. Improvement in cupellation, the use of the bellows, etc., cut down the losses, and the metal available, however, was still not sufficient.

The production of manganese due to cold by ladle additions of ferromanganese in the factory service in India

It was not until a considerable loss of manganese steel was made that the basic manganese slag was exactly as for carbon steel, brought to the proper temperature, to be added immediately. After this, later the ferro-manganese was added and finished under a single slag. During the melt down, manganese and manganese

Low-carbon, low-tar
manganese is brought into the furnace
cold. Power is turned on, and
Practically no air enters the furnace.
Oxides of the charge are reduced
in the melt that manganese is
melted in the electric furnace with

on High-Manganese Steels

el has been considerably increased, due to its peculiar merit in Resisting Abrasion.

CONTRACTION DIFFICULTIES.

to the high contraction of manganese steel, many unsatisfactory and weakened castings ed. The proper use of chills in moulds at the junction of two different thicknesses of metal l the rates of cooling and materially assist in eliminating cracking. Castings should be soon as the metal has solidified, and after they have cooled sufficiently they are shaken e of unusual design, in which the stresses are more difficult to control, are shaken out hot in a heat-treatment furnace. Care must be exercised in the transfer from mould to oven.

MELTING.

ally Hadfield melted low phosphorus, low sulphur pig iron in a cupola and then transferred o a converter, in which he removed practically all impurities, producing dead metal, and y added molten ferro-manganese to produce the required analysis. One of the chief ncountered in this process was the inability to use old heads, gates, and other manganese ut the attendant loss of manganese, due to oxidation during melting. Air furnaces were certain extent, but manganese scrap continued to accumulate, awaiting the discovery of retaining the manganese content of the scrap. Advantage was taken of the so-called actice of blowing converter metal, utilising the manganese content as a source of heat. nt in cupola practice of melting ferro-manganese by the use of a low-blast, low coke-ratio, own the loss of manganese in the melting of ferro-manganese. With all the improvements however, there was a considerable loss of manganese during melting.

roduction of manganese steel by the open-hearth process was handicapped by the fact that ble to refine a charge containing manganese steel scrap without the loss of most of the due to oxidation. Hence, all manganese steel made in the open-hearth has been made ditions of ferro-manganese. While it is possible to make excellent manganese steel by ons of ferro-manganese, and many tons of open-hearth manganese steel have given satis- vice in industry, there are many difficulties associated with this method.

not until the advent of the electric furnace that manganese scrap could be used without ble loss in the manganese content. The first electric furnace melting practice used for steel was similar to that used for carbon steel. A basic bottom was used because the anese slag attacks an acid lining. Soft steel scrap was melted under reducing conditions or carbon steel. Finally, the required amount of ferro-manganese was added, the bath the proper temperature and tapped. Soon it was found that the ferro-manganese could mmediately after slagging off, the subsequent practice remaining unchanged. A little ro-manganese was added immediately after the heat was melted, and then the heat was er a single slag. Later, full advantage was taken of the neutral atmosphere of the furnace melt down, and the reducing action of the carbide slag, permitting the melting of ferro- and manganese scrap from a cold charge and finishing under a single carbide slag.

CHARGING THE FURNACE.

arbon, low-phosphorus steel scrap, manganese-steel scrap, and sufficient ferro-manganese manganese content of the bath, when melted, almost to the specifications, are charged furnace. The manganese steel scrap may constitute practically the whole of the charge, ed on, using high voltage for melting down, in order to shorten the time of this operation. no air enters the furnace, and any oxidation results almost entirely from the rust and charge. It is due to this fact and to the presence of a carbide slag during the finish of at manganese scrap and ferro-manganese can be added with the initial charge in the ace without the loss of manganese that occurs in the converter and open-hearth furnace.

FINISHING AND

When the charge is melted added, and lime, fluor-spar, and voltage in order to protect the as indicated by the laboratory an raising carbon, silico-manganese vigorously, and proper additions

STRUCTURE.

Manganese steel as cast is treatment. It has an austenitic the austenite grains and scatter necessary to convert the structure solution. A high-temperature t manganese content, and rapid qu

Although annealing will effect maximum amount of carbide to the austenitic grains. Slow cool compositions to become martensitic a manganese steel has been weaker toughness by reheating to a higher or chemical separation.

In operating the annealing fu stresses, and when the temperatu before raising to the quenching te on soaking at the higher tempera to 1,050° C., and the castings sub heat for several hours in order to for this operation varies from fo casting. The water in the quench before there is time for any int

CLEANING.

The proper cleaning of manganese adheres after the casting comes off all the trimming must be done by manganese steel foundry. Due to the by grinding, and elaborate mach gradual introduction of new cutting tools instead of grinding, but the

Notes on High-Manganese

field for the use of High-Manganese Steel has been considerably increased, due to

Sir Robt. Hadfield finally produced steel, or more commonly as manganese. The first use of this steel was experienced parts of grey pig iron and manganese magnet. Many years later, about 1875, Sir Robert A. Hadfield used manganese oxide, a fluxing agent. He noted the non-carbon content was too high to give much experimental work was carried manganese were made, and the results of steel containing much over 1.0% of manganese. In 1875 included an alloy containing 1.0% manganese—and the steel was reported to be manganese alloys, Sir Robert A. Hadfield's invention of a steel which not only made much research work has been involved in determining the result of which the commercial range has been increased.

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It was not until the advent of the electric furnace that manganese scrap could be melted without a considerable loss in the manganese content. The first electric furnace melting manganese steel was similar to that used for carbon steel. A basic bottom was used, as basic manganese slag attacks an acid lining. Soft steel scrap was melted under a slag, exactly as for carbon steel. Finally, the required amount of ferro-manganese was added to the proper temperature and tapped. Soon it was found that the ferro-manganese could be added immediately after slagging off, the subsequent practice remaining unchanged until later the ferro-manganese was added immediately after the heat was melted, and the melt was finished under a single slag. Later, full advantage was taken of the neutral atmosphere of the furnace during the melt down, and the reducing action of the carbide slag, permitting the melting of manganese and manganese scrap from a cold charge and finishing under a single slag.

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Low-carbon, low-phosphorus steel scrap, manganese-steel scrap, and sufficient manganese to bring the manganese content of the bath, when melted, almost to the specified percentage, are cold into the furnace. The manganese steel scrap may constitute practically the whole charge. Power is turned on, using high voltage for melting down, in order to shorten the time required. Practically no air enters the furnace, and any oxidation results almost entirely in the formation of oxides of the charge. It is due to this fact and to the presence of a carbide slag that it is possible to melt that manganese scrap and ferro-manganese can be added with the iron in the electric furnace without the loss of manganese that occurs in the converter and open-hearth

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3.

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sufficient ferro-manganese specifications, are charged into the whole of the charge, in the time of this operation, entirely from the rust and carbide slag during the finish of the initial charge in the electric and open-hearth furnace.

FINISHING AND MAKING UP THE COMPOSITION.

When the charge is melted the bath is stirred and a laboratory test is taken. Ferro-silicon is added, and lime, fluor-spar, and coke added to form a slag. The furnace is operated under a lower voltage in order to protect the refractories, and the refining operation begins. Necessary additions, as indicated by the laboratory analysis, are then made. If it is desired to raise the manganese without raising carbon, silico-manganese, or low-carbon ferro-manganese are added. The bath is stirred vigorously, and proper additions are made to form a carbide slag.

STRUCTURE OF MANGANESE STEEL.

Manganese steel as cast is almost glass hard and brittle, and must be made ductile by heat-treatment. It has an austenitic structure, with carbides segregated along the grain boundaries of the austenite grains and scattered throughout the grain itself. Heat-treating and quenching is necessary to convert the structure into austenite by dissolving the carbides and retaining them in solution. A high-temperature treatment is necessary, due to the obstructive action of the high manganese content, and rapid quenching prevents the carbides separating from the solution again.

HEAT TREATMENT.

Although annealing will effect a change in the grain size, it is likely to cause, on slow cooling, the maximum amount of carbide to be rejected by the austenite, forming a weak membrane around the austenitic grains. Slow cooling has a very injurious effect, and there is a tendency for certain compositions to become martensitic under such conditions, a change which should be avoided. When a manganese steel has been weakened by slow cooling from 700° C., it can only be given its characteristic toughness by reheating to a higher temperature and then cooling rapidly enough to prevent mechanical or chemical separation.

In operating the annealing furnaces, it is necessary to heat the castings slowly to reduce expansion stresses, and when the temperature has been raised to about 870° C. they should be allowed to soak before raising to the quenching temperature: this obviates the excessive oxidation that would occur on soaking at the higher temperature. The temperature in the furnace is then raised to from 1,000° to 1,050° C., and the castings subsequently quenched in water. The castings must be given a soaking heat for several hours in order to bring the molecules into a state of equilibrium. The time required for this operation varies from four to twenty-four hours, depending on the size and character of the casting. The water in the quenching tanks should be as cold as possible to cool the castings quickly before there is time for any internal structural changes.

CLEANING AND MACHINING CASTINGS.

The proper cleaning of manganese steel castings presents many problems. Very little sand adheres after the casting comes from the quenching bath, but the metal is so tough that practically all the trimming must be done by grinding. Extensive portable electrically-driven grinding equipment is necessary for this purpose, and the grinding department is a very important part of a manganese steel foundry. Due to the toughness of these steels, all finished work has usually been done by grinding, and elaborate machines have been installed in machine-shops for that purpose. The gradual introduction of new cutting materials are showing the possibilities of machining to size with tools instead of grinding, but the latter method is likely to prevail for many years.



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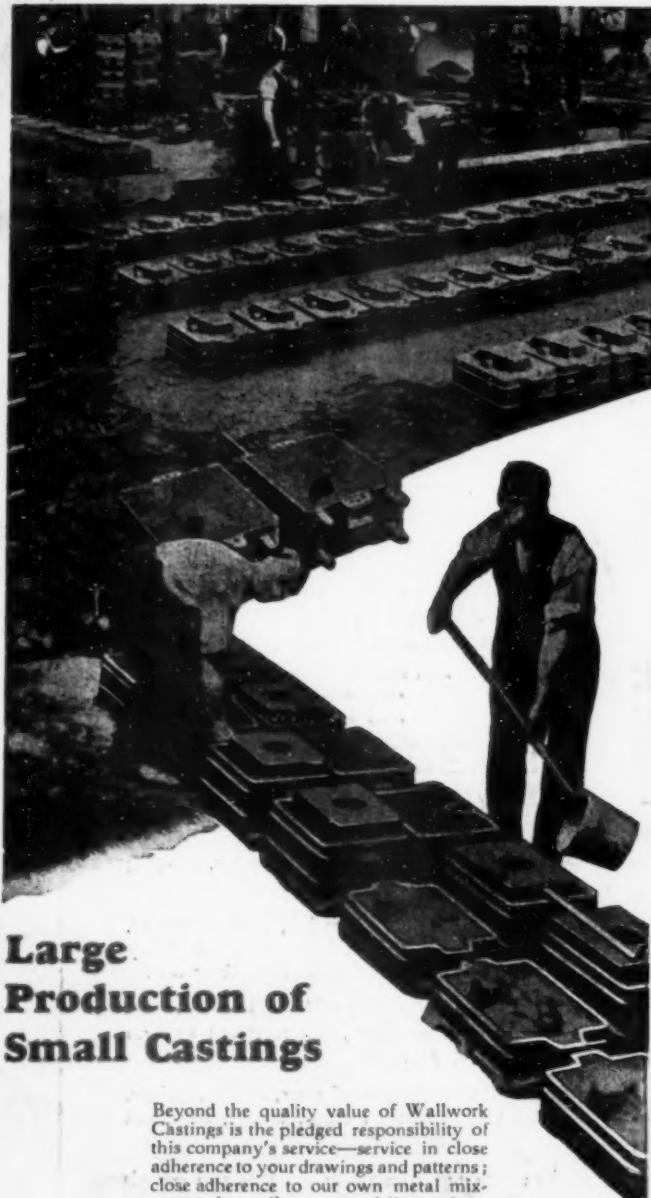
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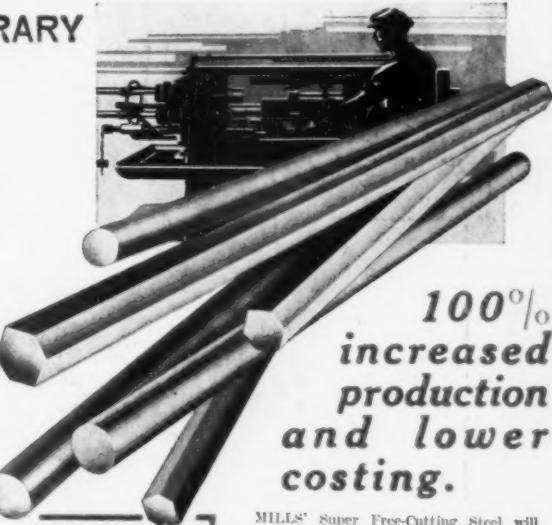
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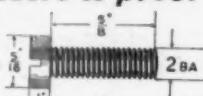
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Silicon-Copper

THE properties of the silicon copper alloys have been examined in the form of wire up to 1.0% silicon, in the cast condition up to 6.5% silicon, and in the form of sheet up to 5.0% silicon; silicon-manganese-copper alloys have been made containing up to 5.0% silicon and 5.0% manganese, and their properties investigated in the cast and rolled conditions. Corrosion and oxidation tests have been carried out on silicon-copper and silicon-manganese-copper sheet. The results of these investigations were presented in the form of a paper, at the Autumn Meeting of the Institute of Metals, at Southampton, by E. Voce, M.Sc., Ph.D., of the British Non-Ferrous Research Association, from which the following has been extracted.

THE PROPERTIES OF CAST SILICON-COPPER ALLOYS.

With silicon contents ranging from 3.0 to 6.5% round bars were cast vertically in chill moulds without difficulty. These were machined for tensile strength test, and the machining qualities proved to be excellent. Certain test-pieces were annealed for 1½ hours at 750° to 800°C. to destroy the cored structure. The results are shown in Table I., in which a number of tin and aluminium bronzes are included for comparison. This table also includes figures for the Brinell hardness of the bars, obtained by the use of a 1-mm. ball under a load of 10 kg.

A ½-in. bar containing 3.0% silicon cast as for tensile tests, was bent through an angle of 180° in the cold without showing the least sign of cracking.

A flat ingot containing 3.0% silicon was prepared ½ in. thick. One end was subjected, in the cold state, to repeated blows until marked cracking occurred. The thickness had been reduced from 0.25 in. to 0.12 in., or 50% on the original. The other end was heated to full redness, and in that condition received the same treatment. The malleability was greater, the thickness having been reduced to 0.04 in., or by 80%, and the temperature having fallen below red heat before cracking commenced.

Table I.—Comparison of Mechanical Properties of Cast Silicon-Copper with Tin-Bronze and Aluminium-Bronze.

Material	SILICON COPPER.						TIN-BRONZE.			ALUMINIUM-BRONZE.		
	Si 3.0%		Si 4.5 to 4.8%		Si 6.5%		Admiralty gun-metal	Phosphor bronze	Al 10%	Al 9.4% Ni 7.4% Fe 4.1%	Al 10.2% Fe 2.8%	
Composition	Chill- cast ½-in. bars	Chill- cast 1-in. bars	Chill- cast and annealed	Chill- cast ½-in. bars	Chill- cast and annealed	Chill- cast ½-in. bars	Cast	Cast and annealed	Cast	Cast	Chill- cast	Die-cast
Condition	Chill- cast ½-in. bars	Chill- cast 1-in. bars	Chill- cast and annealed	Chill- cast ½-in. bars	Chill- cast and annealed	Chill- cast ½-in. bars	Cast	Cast and annealed	Cast	Cast	Chill- cast	Die-cast
Limit of proportionality, Tensile, Tons/in.²	—	2.62	2.93	—	1.79	—	—	3.29 (3.34)	—	4.49	2.300	—
Yield point, Tensile, Tons/in.²	7.95	6.88	5.55	12.56	11.55	—	15.15	10.62	—	—	11.000	—
Ultimate tensile strength, Tons/in.²	16.9	14.87	14.65	19.6	18.14	16.33	14.55	15.82	16.44	15.8	12.5-6.5	11.5-2.5
Elongation % on 2 in.	29.0	23.5	36.5	12.25	11.0	15.5	0.0	6.24	21.07	11.0	9.00	5.5
Reduction of area, %	52.3	40.9	46.9	24.6	14.7	17.5	1.2	—	21.73	7.99	28.00	15.5
Brinell hardness	—	81	66	—	100	95	—	—	—	86	112.2	188.2
							+	80.4	—	—	—	168.5

* Aeronautical Research Committee Report, 1920; results due to Professor E. C. Lea (gun-metal, Sn 10.2, Zn 3.9; phosphor-bronze, Sn 12.55, Zn 1.01, P 0.24).

† Longbottom and Campion, *Trans. Inst. Eng. Ship. Scotland*, 1914.

‡ Rolfe, *J. Inst. Metals*, 1919, 22, 213 (average of 261 tests).

§ H. S. and J. S. G. Primrose, "Gun-Metal and Brass Founding," Cassier, 1920.

|| Rowe, *J. Inst. Metals*, 1918, 21, 175.

¶ U.S. Bureau of Standards, Circular No. 101, "Physical Properties of Metals," p. 50 (Stone's gear bronze, Sn 11, P 0.3).

** A. R. Moore, *Proc. Amer. Soc. Test. Mat.*, 1924, 24, (II), 352.

†† Carpenter and Edwards, "Eighth Report of the Alloys Research Committee," *Proc. Inst. Mech. Eng.*, 1907.

‡‡ Genders and Reader, R.R.A. 81 (Die-Casting Alloys Research, Section I).

§§ Genders, Reader, and Foster, *J. Inst. Metals*, 1928, 110, 198.

† Proof stress.

Iron and Silicon-Manganese-Copper Alloys

THE MECHANICAL AND ELECTRICAL PROPERTIES OF SILICON COPPER WIRE.

A series of alloys was prepared covering a range of 0.0 to 1.0% silicon, and were rolled and drawn into wire by a similar procedure to that adopted for high-conductivity copper. The wire was tested mechanically at various stages in its production, and electrically in the final hard-drawn condition. Six alloys were prepared, using electrolytic copper and 10% cupro-silicon, and cylindrical bars cast in split chill moulds. The outer skin was removed before passing in the mills. The bars were broken down by rolling cold from 1 in. diameter to $\frac{1}{4}$ in. square rod. This was performed in nine passes with ease and without intermediate annealing. Details of the sizes of dies used as well as the results for ultimate strength are given in Table II.

Table II.—The Drawing Conditions and Tensile Strength of Hard Silicon-Copper Wire.

Draw number	" Bolt "	" Bolt "	1	2	3	4	5	6	7	8	9
Mean diam. of wire (in.)	About $\frac{1}{4}$	About $\frac{1}{4}$	0.2422	0.1913	0.1504	0.1181	0.0934	0.0773	0.0643	0.0544	0.0501
Percentage cold-work (percentage reduction or area on 0.6 sq. in.)	{ 0.0 Annealed } 89.16	90.22	95.22	97.05	98.17	98.69	99.22	99.47	99.62	99.80	
Casting, Silicon, Iron, % %											
Ultimate Tensile Strength in Tons per Sq. In.											
1A {	0.076	0.040	16.1	27.8	—	—	—	—	—	—	35.0
1B {			16.2	27.8	30.1	31.3	31.4	32.4	32.9	33.4	34.2
2A {	0.181	0.188	17.9	28.7	30.6	31.7	32.4	32.9	33.7	34.4	35.3
2B {			17.8	27.3	30.2	31.4	32.8	33.1	33.8	34.8	35.2
3A {	0.302	0.027	16.9	29.0	—	—	—	—	—	—	36.7
3B {			16.7	28.4	—	—	—	—	—	—	
5A {	0.433	0.058	17.7	28.8	32.4	33.4	33.8	34.8	35.1	35.4	—
5B {			17.3	28.7	32.3	33.8	34.4	34.3	35.6	36.4	39.7
7A {	0.697	0.042	18.5	31.6	—	—	—	—	—	—	45.9
7B {			18.0	30.8	35.1	36.5	37.7	38.4	40.4	40.9	43.3
10A {	0.902	0.063	19.2	33.9	38.0	40.2	41.7	41.5	41.0	45.3	48.6
10B {			19.7	33.5	37.2	38.6	41.9	43.2	43.8	46.1	48.4

Each figure given for the tensile strengths above is the mean of about half-a-dozen independent tests.

Table III.—The Electrical Resistance of Hard-Drawn Silicon-Copper Wire.

Composition.	Reference Mark of Casting.	Resistance in ohms mile, Corrected to 0°C. and 0.050 in. Diam. Wire.		Specific Resistance in Microhms/cm. Cube.	
		As Observed.	Mean.		
0.076	0.040	{ 1A 1B	38.539 37.931	38.235	2.02
0.181	0.188	{ 2A 2B	65.787 63.778	64.783	5.10
0.302	0.027	{ 3A 3B	57.921 57.328	57.625	4.54
0.433	0.058	{ 5A 5B	70.687 71.126	70.907	5.58
0.697	0.042	{ 7A 7B	95.003 94.931	94.967	7.48
0.902	0.063	{ 10A 10B	121.83 121.44	121.635	9.58

All the wires at the final stage of reduction passed the Post Office standard of wrapping three times on and off their own diameter. In many cases five wraps were recorded.

The electrical resistances of the wires at their final stage of reduction were determined by the "bridge" method in the works of Messrs. Elliott's Metal Co., Ltd. The results obtained on specimens one-hundredth of a mile in length were corrected for variation of gauge and temperature, and as shown in Table III.

THE PR

Strip ingots, each with compositions, nominally cold.

Both compositions cracked at the first pass, copper sheet possesses ve

Extensive corrosion to upon both silicon-copper a the general results being

Copper and silicon-copper was moderately at quite well, the rate of att

Normal sulphuric acid corrosive as the same acid silicon alloys, but decinor concentration. All metal (8 to 15 mg. per sq. cm. pe

The corrosion of a silicon-manganese-copper identical conditions, but

Tab

Analysis.		Thickness of Sheet, in.	Hot or Cold-Rolling.
Silicon, %	Iron, %		
4.58	0.28	0.137	Hot
2.51	0.26	0.139	Hot
3.23	0.29	0.128	Cold
3.23	0.29	0.065	Cold
3.23	0.29	0.034	Cold

Silicon-Copper and Silicon-Mangan

examined in the form of wire up to 1 in. and in the form of sheet up to 5·0% silicon, and in the cast and rolled conditions. Corrosion resistance and silicon-manganese-copper sheet, in the form of a paper, at the Autumn Meeting of the British Non-Ferrous Metals Research Association, Ph.D., of the British Non-Ferrous Metals Research Association.

CON-COPPER ALLOYS.

bars were cast vertically in chill moulds for strength test, and the machining qualities for 1½ hours at 750° to 800°C. to destroy which a number of tin and aluminium figures for the Brinell hardness of 10 kg.

tests, was bent through an angle of 180°

thick. One end was subjected, in the other. The thickness had been reduced from 1 in. was heated to full redness, and in that was greater, the thickness having been fallen below red heat before cracking

Properties of Cast Silicon-Copper and Tin-Bronze.

TIN-BRONZE.		ALUMINUM-BRONZE.	
Admiralty gun-metal	Phosphor bronze	Al 10% (Ni 7·4% Fe 4·1%)	Al 10% (Ni 7·4% Fe 2·8%)
Cast	Cast	Cast	Chill-cast
3·2%	—	4·4%	2·3%
10·6%	—	—	11·0%
15·8%	—	8·9%	14·1%
13·3%	—	10·11%	11·4%
15·6%	18·0%	13·49%	26·5%
14·5%	—	16·44%	15·8%
6·2%	21·0%	15·8%	29·32%
12·6%	32·0%	6·11%	17·0%
—	28·0%	—	28·0%
—	—	86%	112%

Admiralty gun-metal, Sn 10·2, Zn 3·9; phosphor-bronze, Sn 12·55,

50 (Stone's gear bronze, Sn 11, P 0·3).

see, *Inst. Mech. Eng.*, 1907.

* Proof stress.

THE MECHANICAL AND ELECTRICAL PROPERTIES OF SILICON COPPER WIRE.

A series of alloys was prepared covering a range of 0·0 to 1·0% silicon, and were drawn into wire by a similar procedure to that adopted for high-conductivity copper. The wire was mechanically at various stages in its production, and electrically in the final hard-drawn condition. Six alloys were prepared, using electrolytic copper and 10% cupro-silicon, and cylinders were drawn in split chill moulds. The outer skin was removed before passing in the mills. The wire was drawn down by rolling cold from 1 in. diameter to 1/4 in. square rod. This was performed in a single pass, with ease and without intermediate annealing. Details of the sizes of dies used as well as the ultimate strength are given in Table II.

Table II.—The Drawing Conditions and Tensile Strength of Hard Silicon-Copper Wire.

Draw number	" Bolt "	" Bolt "	1	2	3	4	5	6
Mean diam. of wire (in.)	About 1	About 1	0·2422	0·1913	0·1501	0·1181	0·0934	0·0773
Percentage cold-work (percentage reduction in area on 0·6 sq. in.)	0·0 Annealed	89·16 90·22	95·22	97·05	98·17	98·49	99·22	99·44
Casting.	Silicon, %	Iron, %	Ultimate Tensile Strength in Tons per Sq. In.					
1A	0·076	0·040	16·1	27·8	—	—	—	—
1B	—	—	16·2	27·8	30·1	31·3	31·4	32·4
2A	0·181	0·188	17·9	28·7	30·6	31·7	32·4	32·9
2B	—	—	17·8	27·3	30·2	31·4	32·8	33·1
3A	0·302	0·027	16·9	29·0	—	—	—	—
3B	—	—	16·7	28·4	—	—	—	—
5A	0·433	0·058	17·7	28·8	32·1	33·4	33·8	34·8
5B	—	—	17·3	28·7	32·3	33·8	34·4	35·6
7A	0·697	0·042	18·5	31·6	—	—	—	—
7B	—	—	18·0	30·8	35·1	36·5	37·7	38·4
10A	0·902	0·063	19·2	33·9	38·0	40·2	41·7	41·5
10B	—	—	19·7	33·5	37·2	38·6	41·9	43·2

Each figure given for the tensile strengths above is the mean of about half-a-dozen independent tests.

Table III.—The Electrical Resistance of Hard-Drawn Silicon-Copper Wire.

Composition.	Reference-Mark of Casting.	Resistance in ohms/mile. Corrected to 0°C. and 0·050 in. Diam. Wire.		Specific Resistance in Microhms/cm. Cube.
		Silicon, %	Iron, %	
0·076	0·040	1A 1B	38·539 37·931	3·02
0·181	0·188	2A 2B	65·787 63·729	5·10
0·302	0·027	3A 3B	37·921 37·328	4·54
0·433	0·058	5A 5B	70·687 71·126	5·58
0·697	0·042	7A 7B	95·003 94·931	7·48
0·902	0·063	10A 10B	121·82 121·44	9·58

All the final stage passed the standard of wrapping on and off meter. In the

The electrical properties of the wires at the stage of the determined by the method in Messrs. Elliott & Co. Ltd. The resistance of the wires of a mile is corrected for gauge and temperature as shown in

Japanese-Copper Alloys.

PROPERTIES OF

and were rolled and drawn over. The wire was tested in the hard-drawn condition, and cylindrical bars cast. The bars were broken in nine passes with as well as the results for

Silicon-Copper Wire.

6	7	8	9
0.0773	0.0643	0.0544	0.0501
99.22	99.47	99.62	99.80

sq. in.

—	—	—	35.0
33.4	33.9	34.4	34.2
34.4	34.8	35.3	35.4
34.8	35.0	35.2	34.9
—	—	—	36.7
35.4	37.5	39.2	—
36.4	37.6	38.1	39.7
—	42.1	43.3	46.0
45.3	47.6	48.6	49.6
46.1	48.3	48.4	49.7

independent tests.

All the wires at the first stage of reduction met the Post Office standard of wrapping three times and off their own diameter. In many cases five passes were recorded.

The electrical resistances of the wires at their final stage of reduction were determined by the "bridge" method in the works of Messrs. Elliott's Metal Co.,

The results obtained on specimens one-hundredth of a mile in length were corrected for variation of size and temperature, and are shown in Table III.

THE PROPERTIES OF SILICON-COPPER SHEET.

Strip ingots, each weighing 25 lb., were cast for rolling into sheets. The ingots were of two compositions, nominally 3 and 5% silicon. One ingot of each composition was rolled hot, the other cold.

Both compositions were successfully rolled hot at about 750° C. In the cold the 5% alloy cracked at the first pass, while the 3% silicon rolled excellently. As indicated in Table IV., silicon-copper sheet possesses very special mechanical properties.

RESISTANCE TO CORROSION.

Extensive corrosion tests in various liquids, including mineral and organic acids, were undertaken upon both silicon-copper and silicon-manganese-copper, with pure copper as a standard of reference, the general results being briefly summarised as follows:—

Copper and silicon-copper resisted strong sulphuric acid fairly well, but silicon-manganese-copper was moderately attacked. All metals, however, resisted normal and decinormal sulphuric acid quite well, the rate of attack being from 8 to 13 mg. per sq. cm. per month.

Normal sulphuric acid containing dissolved sulphates (mine water) is three or four times as corrosive as the same acid free from sulphates. Normal nitric acid rapidly attacks copper and the silicon alloys, but decinormal nitric acid has scarcely more action than sulphuric acid of the same concentration. All metals showed a fair degree of resistance to normal formic and acetic acids (8 to 15 mg. per sq. cm. per month), and mixing the two acids did not increase the rate of attack.

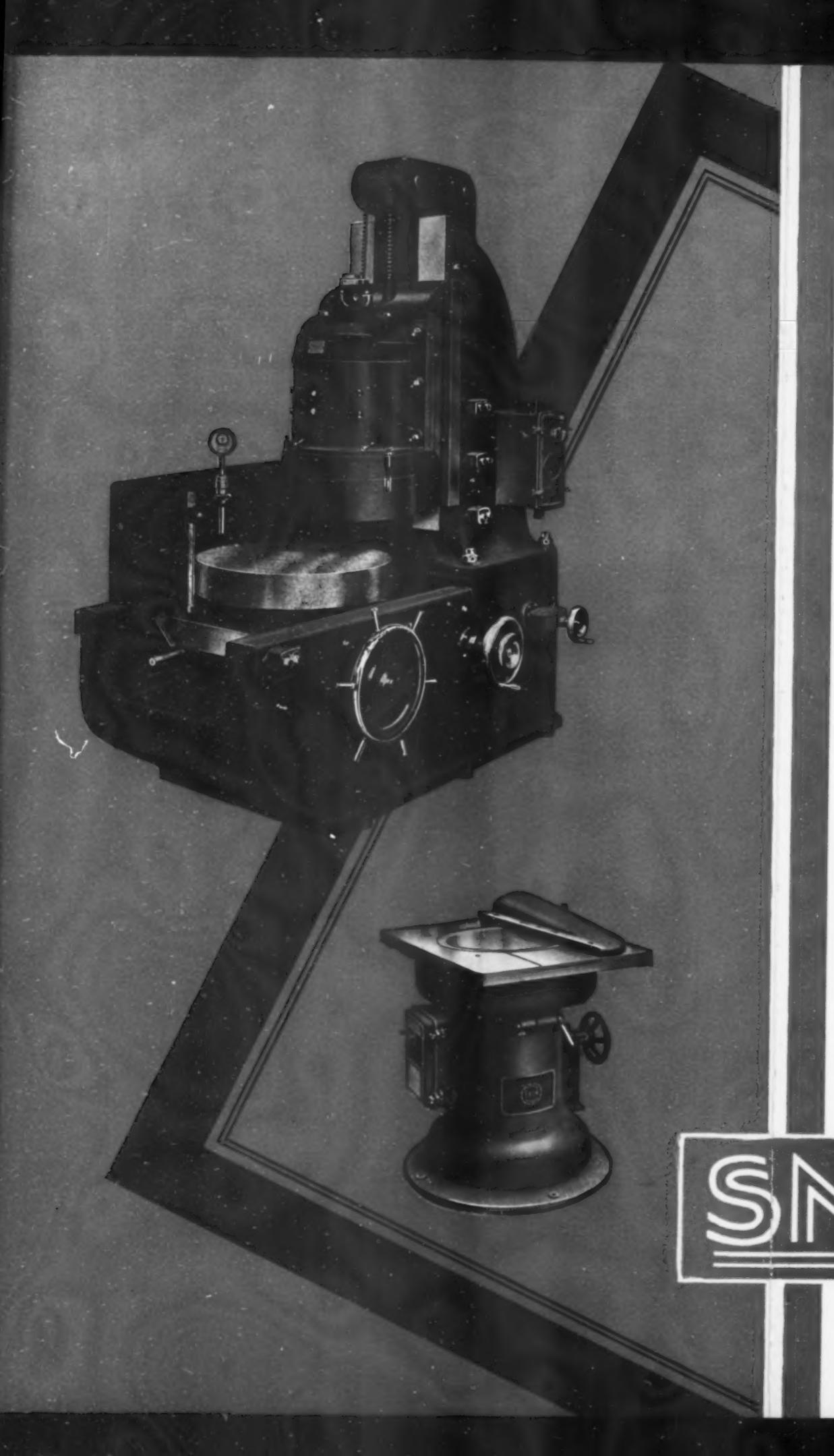
The corrosion of a silicon-copper alloy, containing 4.5% silicon, proved very similar to that of a silicon-manganese-copper alloy, containing 3.17% silicon and 0.99% manganese, tested under identical conditions, but was rather less severe.

Table IV.—The Properties of Silicon-Copper Sheet.

Analysis.		Thickness of Sheet, in.	Hot- or Cold-Rolling.	Condition.	Cold-Work.	Direction of Test Relative to that of Rolling.	Yield Point, Tons/sq. in.	Ultimate Stress, Tons/sq. in.	Percentage Elongation—			Brinell Hardness, 1-mm. Ball under 10-kg. Load.
Silicon, %	Iron, %								on 2in.	on 4 √ Area.	Reduction of Area, %	
4.58	0.28	0.137	Hot	As rolled	—	Longitudinal	17.3	38.6	11.0	13.5	11.6	173.5
						Transverse	19.3	39.8	5.5	6.4	7.1	
						Longitudinal	7.3	33.0	32.0	32.6	21.9	
2.51	0.26	0.139	Hot	As rolled	—	Transverse	11.8	32.6	20.5	19.5	15.3	—
						Longitudinal	6.9	24.3	66.0	72.1	57.4	
						Transverse	6.4	25.1	46.0	46.2	35.9	
3.23	0.29	0.128	Cold	As rolled	50	Longitudinal	6.9	22.7	71.5	80.9	58.4	—
						Transverse	7.4	23.3	62.0	64.3	34.2	
						Longitudinal	—	—	—	—	—	
3.23	0.29	0.065	Cold	As rolled	48	Longitudinal	15.7	49.5	7.5	10.0	10.5	178.7
						Transverse	—	49.1	4.5	4.5	2.5	
						Longitudinal	11.1	29.8	53.3	60.0	44.0	
3.23	0.29	0.034	Cold	As rolled	49	Longitudinal	11.0	26.1	32.0	28.9	20.7	70.0
						Transverse	—	—	—	—	—	
						Longitudinal	—	48.3	10.3	9.1	10.4	134.0
3.23	0.29	0.034	Cold	Annealed	0	Transverse	11.2	49.3	9.0	6.1	6.7	
						Longitudinal	12.6	29.2	53.1	70.8	46.2	
						Transverse	11.0	27.3	29.5	29.5	23.5	

Each figure is the mean of several independent tests.

(To be continued.)



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ese facts are all-important; as important as is the any time, of the specialist as against the general practitioner.

ted on this sheet are various types of SNOW Surface covering a wide range of duty. With the exception of the hand-surfacing grinder and the Rotary table machine, ers have oil-hydraulic transmission. Each illustration e, and for each type we have a wide range of sizes, making Segmental System of surface grinding truly universal able to all classes of work where true planes need to be n the shortest time.

nce, there is a SNOW Surface Grinder for flat, thin textile and like parts; a SNOW grinder for heavy castings or forgings, there is a SNOW Surface Grinder for "gang" and a SNOW Duplex Grinder with twin-tables, which oading and grinding operations to proceed simultaneously on.

urface Grinders really are simple in operation. The oil-table drive gives a tremorless swift "glide" of the work nding head; reverse is instant, but velvety and without parts are designed with generous over-load allowances; s are chosen rightly to express the function of each part.

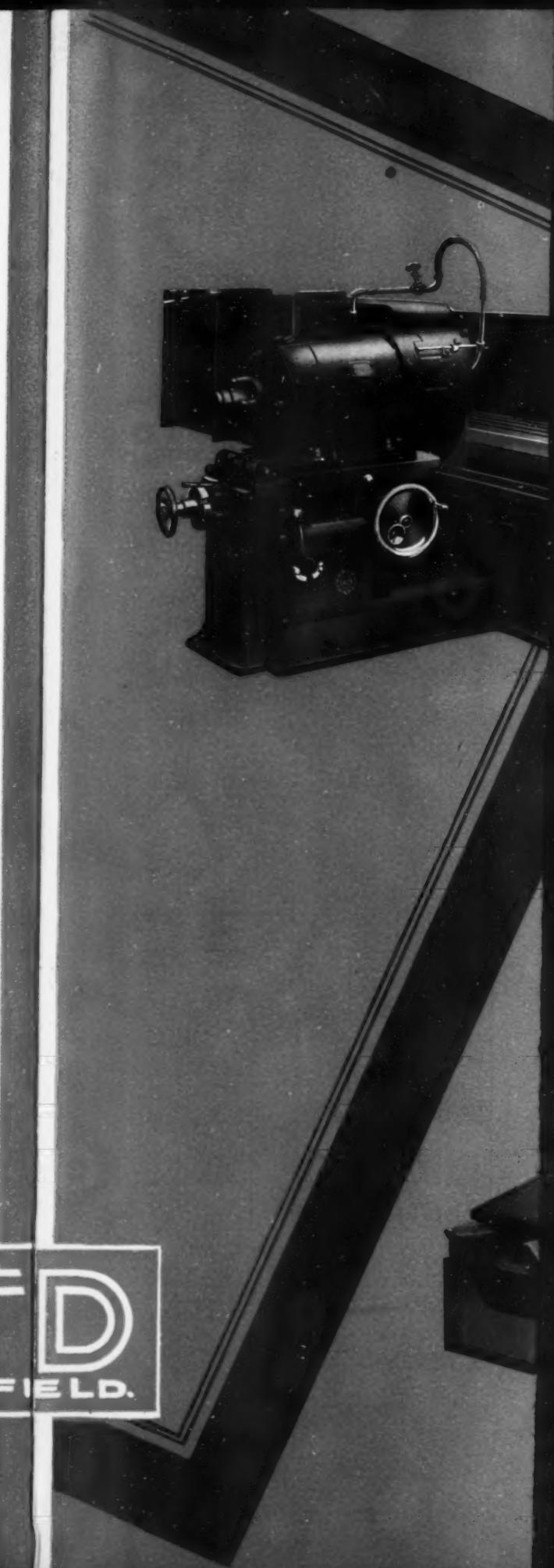
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Illustrated on this sheet are various types of SNOW Surface Grinders, covering a wide range of duty. With the exception of the handy little hand-surfacing grinder and the Rotary table machine, these grinders have oil-hydraulic transmission. Each illustration shows a type, and for each type we have a wide range of sizes, making the SNOW Segmental System of surface grinding truly universal and applicable to all classes of work where true planes need to be generated in the shortest time.

For instance, there is a SNOW Surface Grinder for flat, thin textile machinery and like parts; a SNOW grinder for heavy castings or unwieldy forgings, there is a SNOW Surface Grinder for "gang" grinding, and a SNOW Duplex Grinder with twin-tables, which enable the loading and grinding operations to proceed simultaneously in production.

SNOW Surface Grinders really are simple in operation. The oil-hydraulic table drive gives a tremorless swift "glide" of the work past the grinding head; reverse is instant, but velvety and without shock. All parts are designed with generous over-load allowances; all materials are chosen rightly to express the function of each part.

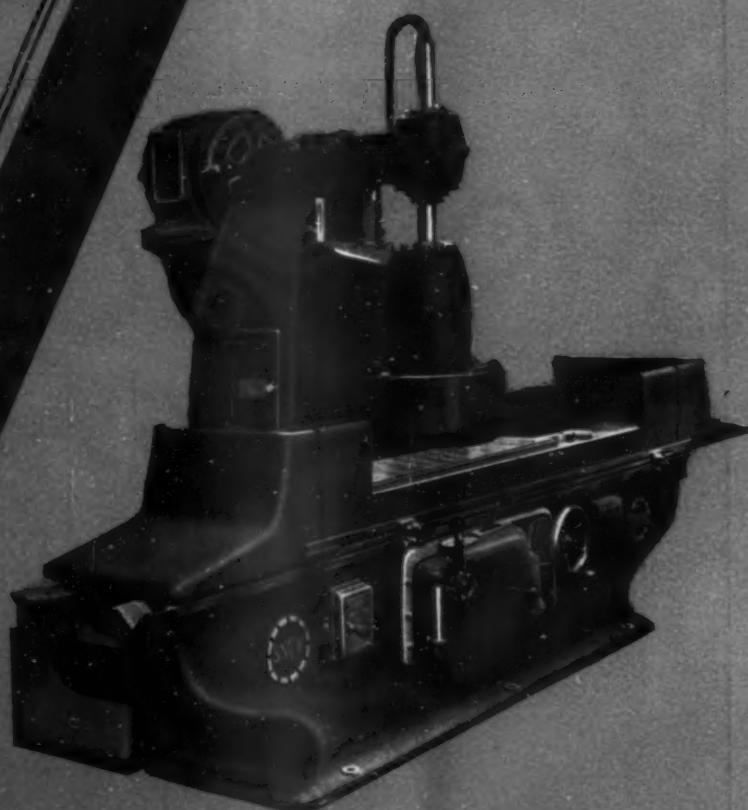
The SNOW System of Segmental Surface Grinders is complete. There is a type and a size to suit you. Particularly if you are planing or plano-milling your surfaces, we would urge you to consider the idea of surface grinding.

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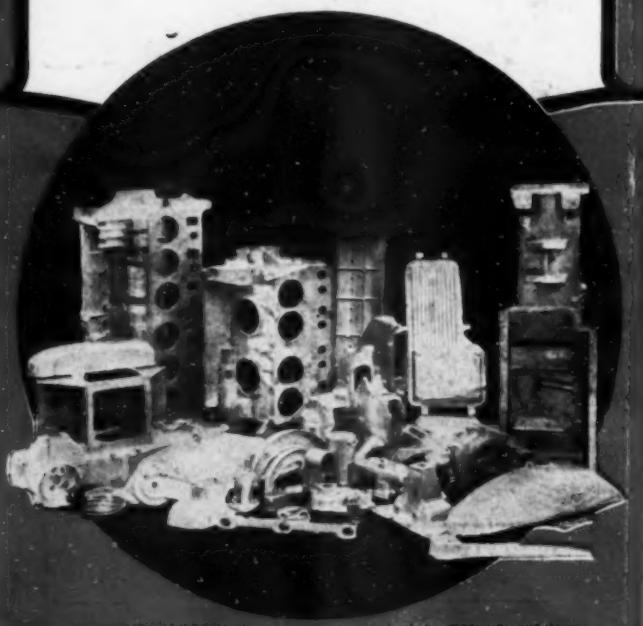
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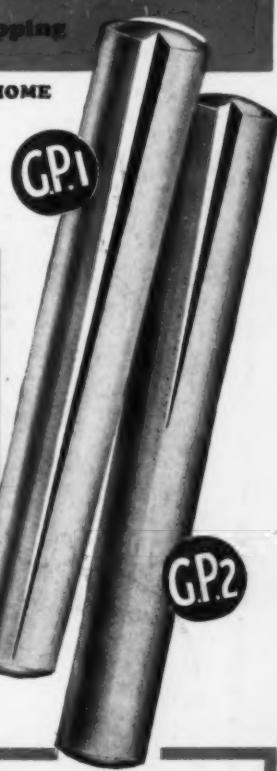
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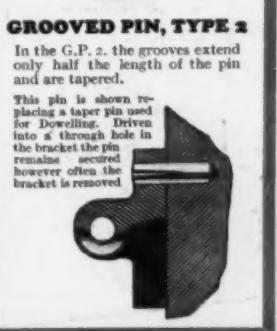
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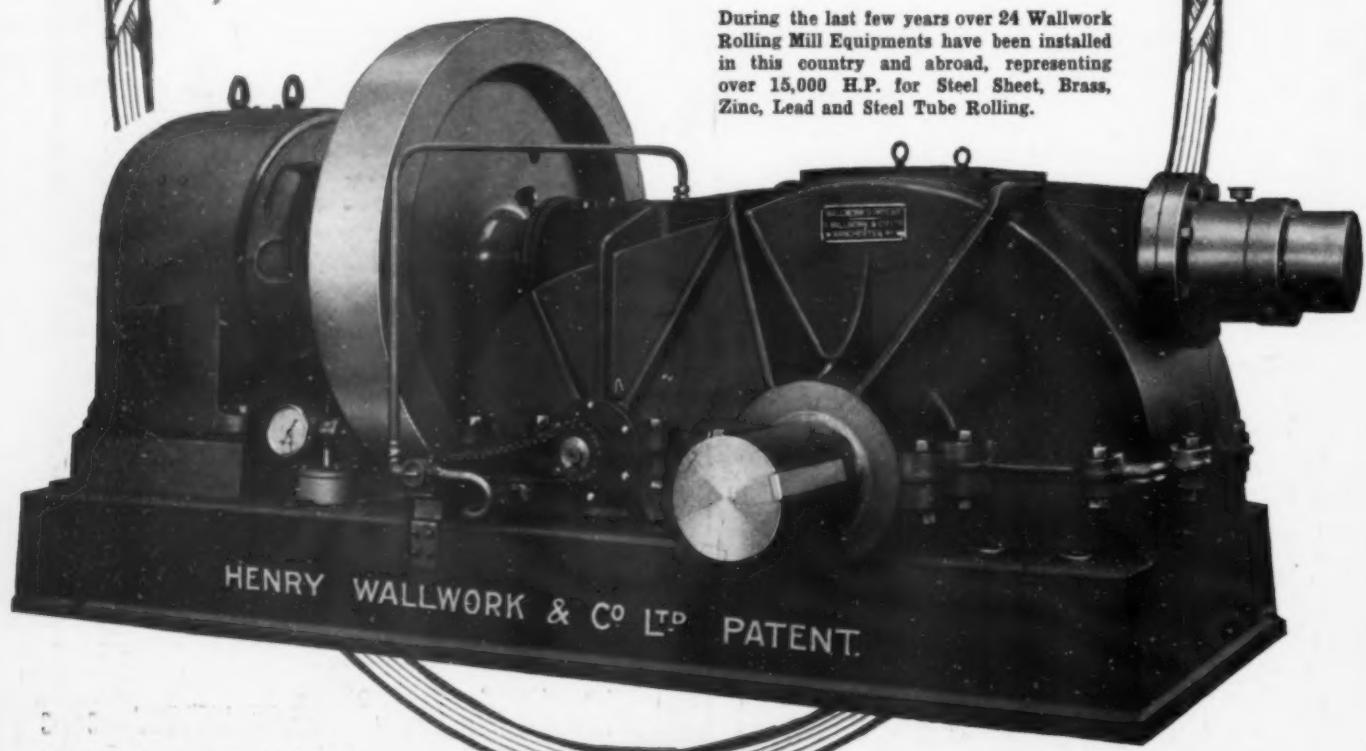


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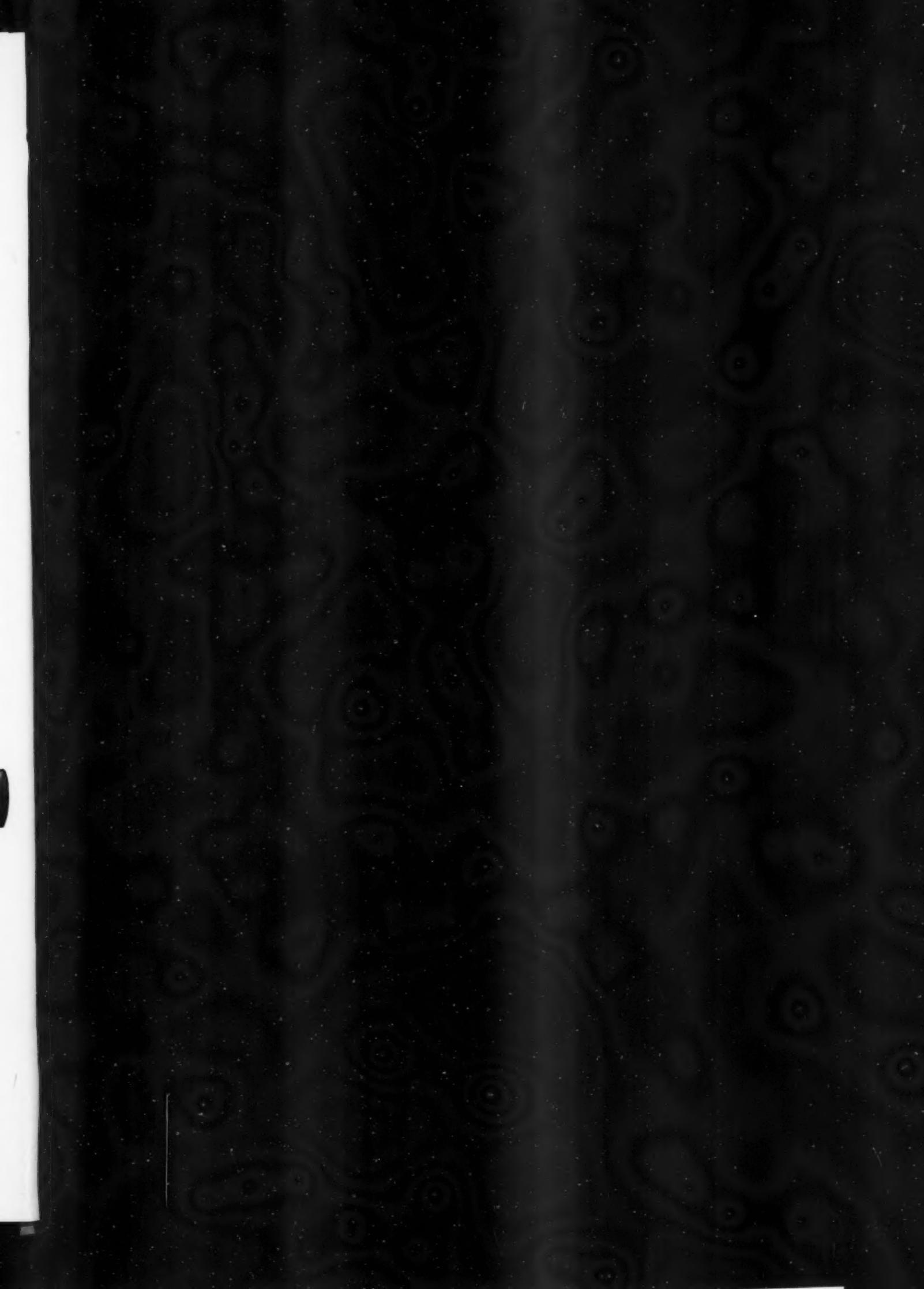
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Silicon-Copper and

PREPARATION OF CAST SILICON-MANGANESE-COPPER ALLOYS.

PRELIMINARY tests apparently indicated that the most useful alloys, combining good strength and hardness with reasonable machinability, were within a somewhat narrow range between 2 and 5% silicon and 0 and 5% manganese. Alloys outside these limits are either too soft to possess any special advantage, or too brittle to be of use for structural or engineering purposes. The compositions, which varied from each other by steps of 1.5% in both silicon and manganese content, were as follows:—

1% manganese with 2%, 3.5%, and 5% silicon; 2.5% manganese with 2% and 3.5% silicon; 4% manganese with 2% silicon.

Two strip ingots, 12 in. \times 4 in. \times $\frac{1}{2}$ in. for sheet, and two round bars, 14 in. \times 1 in. diameter, for tensile tests were poured from one pot of metal for each of these six compositions. The com-

Table V.—Silicon-Manganese-Copper Castings. Analyses of the Castings.

Casting No.	Round Bars.					Strip Ingots.					Silicon, %.		Manganese, %.	
	Silicon, %.	Manganese, %.	Iron, %.	Copper % by Diff.	Ref. Mark.	Silicon, %.	Manganese, %.	Iron, %.	Copper % by Diff.	Ref. Mark.	Mean of Pot of Metal.	Intended.	Mean of Pot of Metal.	Intended.
1A	2.52	0.78	0.13	97.46	R3	3.17	0.99	0.10	95.74	S5	2.17	2.0	0.72	1.0
1B	1.37	0.44	0.04	98.15	R1	1.30	0.44	0.03	98.87	S1				
2A	4.14	1.30	0.07	94.49	R8	3.74	2.01	0.08	94.17	S8	3.39	3.5	1.39	1.0
2B	3.45	1.03	0.04	95.59	R5	2.27	1.08	0.10	96.55	S2				
3A	5.85	1.58	0.17	92.43	R11	5.30	1.21	0.16	93.33	S11	5.09	5.0	1.42	1.0
3B	3.35	1.45	0.12	93.04	R10	4.14	1.51	0.09	94.26	S7				
4A	2.15	1.17	0.05	93.32	R2	2.40	2.53	0.03	93.98	S9	2.13	2.0	2.11	2.5
4B	1.92	1.08	0.07	96.02	R4	1.93	1.45	0.11	96.45	S3				
5A	4.74	3.19	0.12	91.95	R12	3.42	2.72	0.08	93.78	S10	3.60	3.5	2.40	2.5
5B	3.22	2.01	0.08	94.69	R7	3.27	1.82	0.12	94.79	S6				
6A	2.29	4.49	0.12	95.10	R9	2.60	5.53	0.12	91.72	S12	1.92	2.0	3.91	4.0
6B	1.67	3.30	0.10	94.93	R6	1.31	2.26	0.09	96.34	S4				

* The reference mark numbers are in descending order of copper content in each cast.

positions of the castings as found by analysis are given in Table V. In each case the ingot cast first from any pair contained more silicon than the other, although the author states all were well stirred before pouring. Careful analysis of samples from different parts of the castings showed no segregation in any one ingot.

PROPERTIES OF CAST SILICON-MANGANESE COPPER ALLOYS

Each cast cylindrical bar was divided into two parts, 7 in. \times 1 in. diameter, and machined into tensile test-pieces of standard dimensions, giving $\frac{1}{2}$ sq. in. sectional area. The results of these tests are indicated in Table VI. It appears that silicon has a greater effect upon the ultimate strength than manganese, the highest strength being obtained from alloys with silicon contents ranging between 3% and 4.5%. With less silicon the alloys are soft and of poor quality, while with more they become increasingly brittle, owing to the presence of the γ -phase. Within the optimum range of silicon content—namely, 3 to 4.5% silicon—increase of manganese raised the ultimate strength to a certain extent, but only at the expense of ductility. The highest ultimate strength recorded was 26.6 tons per sq. in. for the alloy containing 4.74% silicon and 3.19% manganese; its ductility, however, was low. The alloy containing 3.43% silicon and 1.04% manganese had the greatest elongation of the series—namely, 25%. With 5% silicon and over practically all elongation disappears, while the alloys of relatively high manganese content are not specially ductile.

After tensile tests the castings were sectioned transversely, and the sections used for hardness determination. The Brinell hardness figures obtained by the use of a ball 1 mm. in diameter, under a load of 10 kilogs. applied for 15 secs., are indicated in Table VII. Four ranges were described by reference to the silicon contents, as follows:—

1. From 0 to 2.5 or 3% silicon all the alloys are relatively soft, the higher limit of hardness being about 70 Brinell in the case of the round bars, and 90 for the strip ingots.

2. At about 3% silicon there is fairly rapid increase of about 20 Brinell points in each case, marking the appearance of a new constituent, to the influence of which the increased hardness is doubtless due.

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Table

Ref. Mark in
Order of
Descending
Cu Content.

R1
R2
R3
R4
R5
" Everdur " /
R6
R7
R8
R9
R10
R11
R12

Plain silicon-
copper alloy

Everdur make

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properties

Table VI

Reference
Mark in
Order of
Descending
Copper
Content.

R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12

Plain
silicon
copper
alloys

Silicon-Manganese-Copper Alloys

3. Between 3 and 4% silicon, in an area corresponding almost exactly with that of good ultimate strength, the Brinell number remains at an almost uniform and fairly high value—namely, 90 to 100 for the bars and 110 and 120 for the ingots. Here the best Brinell properties occur.

4. With more than 5% silicon the hardness increases rapidly, owing to the presence of excessive amounts of γ .

Table VI.—The Tensile Properties of Cast Silicon-Manganese-Copper Alloy.

Reference Mark in Order of Descending Copper Content.	Composition, %.			Tensile Test, In.			Young's Modulus, lb. in.^{-2}	Elongation, %, on 2 in. or $\frac{1}{4}$ in. area	Reduction of Area, %.
	Si	Mn	Fe	Ultimate Tensile Strength	Yield Point or Stress for 0.5% Extension	Limit of Proportionality			
R1	1.73	0.44	0.04	9.5	6.0	—	—	9	14
R2	2.15	1.17	0.06	11.0	6.2	1.0	7,500	11	29
R3	2.54	0.78	0.13	14.2	7.0	—	—	16	22
R4	1.39	1.98	0.07	14.4	6.6	2.4	6,300	17	21
R5	3.43	1.04	0.04	21.8	8.2	2.0	7,800	25	14
R6	1.67	3.30	0.10	15.0	7.8	2.8	6,200	20	25
R7	3.22	2.01	0.08	15.3	6.6	2.6	7,900	13	18
R8	1.14	1.30	0.07	21.1	8.1	2.0	6,700	15	14
R9	2.29	4.49	0.12	15.5	9.4	3.6	8,200	15	21
R10	5.35	1.45	0.12	18.5	15.9	5.6	6,200	1	1
R11	5.85	1.58	0.17	18.8	—	11.2	6,800	1	0
R12	4.74	3.19	0.12	21.6	11.0	3.6	6,800	1	6
in silicon- per alloys	3.0	See Tables I. and II.	—	14.9	7.6	2.6	5,600	24	41
	4.5	—	—	18.1	11.2	—	10,700	11	15
	6.5	—	—	14.5	—	—	—	0	0
Everdur makers' tests (cf. R5 above) . . .			22.1	13.4	—	—	21	35	

With one or two exceptions, due to unsoundness, each result given above is the mean of tests upon samples machined from the same casting.

As this figure may not represent stress for 0.5% extension it is scarcely comparative.

Test-pieces were machined from the strip ingots and subjected to the Izod notched-bar test on a 120 ft.-lb. machine, the specimens being of standard dimensions—namely, 1 cm. \times 1 cm. section, notch 2 mm. deep at an angle of 45°, with circular bottom of 0.25 mm. radius. The notches were 28 mm. from the ends of the specimen to be struck. The results of these tests are included in Table VII, from which it may be concluded that, in the chill-cast state, silicon-manganese-copper alloys of about the composition 3.5% silicon and 1% manganese had the best all-round mechanical properties of any between the limits of 0 to 5% each of silicon and manganese.

Table VII.—The Hardness and Impact Value of Cast Silicon-Manganese-Copper Alloys.

Reference Mark in Order of Descending Copper Content.	Round Bars.			Strip Ingots.						Izod Impact Value in Ft.-lb. on a 120 ft.-lb. Machine.			
	Chemical Composition, %.			Hardness Numbers			Izod Impact Value in Ft.-lb. on a 120 ft.-lb. Machine.						
	Si	Mn	Fe	Brinell	Sclerometer	Reference Mark in Order of Descending Copper Content.	Si	Mn	Fe	Brinell	Sclerometer	As Cast	Annealed
R1	1.73	0.44	0.04	62	7	81	1.50	0.54	0.09	68	8	—	—
R2	2.15	1.17	0.06	63	8	82	2.27	1.08	0.10	72	10	45 (unbroken)	44 (unbroken)
R3	2.52	0.78	0.13	67	10	83	1.99	1.45	0.11	68	8	47	44
R4	1.39	1.98	0.07	70	10	84	1.31	2.26	0.03	71	9	50	45
R5	3.43	1.04	0.04	93	15	85	3.17	0.99	0.10	116	16	34	54
R6	1.67	3.30	0.10	65	9	86	3.27	1.82	0.12	86	15	—	—
R7	3.22	2.01	0.08	92	15	87	4.14	1.51	0.03	113	21	22 (broken)	53 (unbroken)
R8	4.44	1.30	0.07	92	17	88	3.74	2.01	0.08	113	19	49	44
R9	2.29	4.49	0.12	76	9	89	2.40	3.55	0.09	86	10	42 (unbroken)	53
R10	5.35	1.40	0.12	148	27	90	5.42	2.72	0.08	99	16	26 (broken)	56
R11	5.85	1.58	0.17	214	37	91	5.30	1.21	0.16	188	36	2	11 (broken)
R12	4.74	3.19	0.12	133	17	92	2.60	3.56	0.12	103	(187)	28	23
in silicon- per alloys	3.0	See Table II.	—	71	—	Everdur No. 50 Metal	31	1	—	—	13-14	Makers' tests; compare with R5, R7, 85, 86.	
	4.5	—	—	100	—								

Each result is the mean of several tests.

Hardness tests were also applied to certain of the Izod specimens prepared from the strip ingots, and it will be noted that the values of the strip ingots are in general about 20 Brinell numbers higher than those from round bars of the same composition, the more severe chilling of the strip ingots accounting for the greater hardness. It will be noted that silicon has more influence upon the hardness than manganese. Scleroscope hardness tests were also performed, using the universal hammer, upon the Brinell specimens, and the results which follow the general trend as the Brinell numbers are included in Table VII. Unlike the Brinell figures, there is no marked discrepancy between the values for the round bars and strip ingots.

PRODUCTION

Of the twelve strip ingots to the following division:

For cold rolling . . .
For hot rolling . . .

With the exception of was obtained by cold-rolling and, for the most part, the is but on cooling off serious to give better results than is maintained above redness material becomes hot short.

PROPERTIES

The results of tensile tests in Table VIII, in which each

Table VIII.—The Tensile Test.

Reference Mark.	Composition, %.			Hard.
	Si	Mn	Fe	Longit. Break.
S1	1.50	0.54	0.09	29.4
S2	2.27	1.08	0.10	35.9
S3	1.99	1.45	0.11	—
S4	1.31	2.26	0.09	33.5
S5	3.17	0.99	0.10	—
S6	3.27	1.82	0.12	41.4
S7	4.14	1.51	0.09	45.5
S8	3.74	2.01	0.08	—
S9	2.40	3.53	0.09	41.6
S10	3.42	2.72	0.08	—
S11	5.30	1.21	0.16	—
S12	2.60	5.56	0.12	—

Longitudinal and transverse relative

of the table reveals the fact that tested across than along the direction (with cross rolling), followed by objectionable directional properties and mill-power economy.

OXIDATION OF SILICON-COPPER ALLOYS

Careful experiments were made on oxidation at a temperature of 725°C. The scale formed on silicon-copper alloys consisted of a black cupric oxide. The resistance of silicon-copper to oxidation increased with the silicon content. At 725°C. the oxidation rate was one-quarter to one-seventh that of pure copper, and also a function of the silicon content, and approximates to that of pure copper.

The addition of 1% of manganese to the silicon-copper alloy rendered the alloy more resistant to oxidation, but rendered the alloy less ductile.

Silicon-Copper and Silicon-Manganese-Alloys

MANGANESE-COPPER ALLOYS.

the most useful alloys, combining good strength were within a somewhat narrow range between

Alloys outside these limits are either too soft to be of use for structural or engineering purposes. At steps of 1·5% in both silicon and manganese

; 2·5% manganese with 2% and 3·5% silicon;

t, and two round bars, 14 in. \times 1 in. diameter, for each of these six compositions. The compositions. Analyses of the Castings.

ip Ingots.			Silicon, %.		Manganese, %.	
Iron	Copper	Ref. Mark.	Mean of Pot of Metal.	Intended.	Mean of Pot of Metal.	Intended.
0·10	95·74	82	2·17	2·0	0·72	1·0
0·08	98·87	81				
0·08	94·17	88	3·39	3·5	1·39	1·0
0·10	96·55	82				
0·16	93·33	811	5·09	5·0	1·42	1·0
0·09	94·26	87				
0·02	93·98	80	2·13	2·0	2·11	2·5
0·11	96·45	83				
0·08	93·78	810	3·60	3·5	2·40	2·5
0·12	94·79	86				
0·12	91·72	812	1·92	2·0	3·91	4·0
0·09	96·34	84				

g order of copper content in each cast.

in Table V. In each case the ingot cast first although the author states all were well stirred rent parts of the castings showed no segregation

MANGANESE COPPER ALLOYS

arts, 7 in. \times 1 in. diameter, and machined into . in. sectional area. The results of these tests as a greater effect upon the ultimate strength deduced from alloys with silicon contents ranging are soft and of poor quality, while with more of the γ -phase. Within the optimum range use of manganese raised the ultimate strength. The highest ultimate strength recorded % silicon and 3·19% manganese; its ductility, con and 1·04% manganese had the greatest n and over practically all elongation disappears, are not specially ductile.

ansversely, and the sections used for hardness by the use of a ball 1 mm. in diameter, under in Table VII. Four ranges were described by

atively soft, the higher limit of hardness being 90 for the strip ingots.

case of about 20 Brinell points in each case, influence of which the increased hardness is

3. Between 3 and 4% silicon, in an area corresponding almost exactly with that of strength, the Brinell number remains at an almost uniform and fairly high value—100 for the bars and 110 and 120 for the ingots. Here the best Brinell properties are

4. With more than 5% silicon the hardness increases rapidly, owing to the presence of γ .

Table VI.—The Tensile Properties of Cast Silicon-Manganese-Copper Alloy.

Ref. Mark in Order of Descending Cu Content.	Composition, %.			Tensile Strength, Tons/sq. in.			Young's Modulus, $\frac{1}{2}$ in. or 1 in. \times $\sqrt{\text{area}}$	Elongation, %, on 2 in. or 1 in. $\sqrt{\text{area}}$	Reduction of Area, %
	Si	Mn	Fe	Ultimate Tensile Strength	Yield Point or Stress for 0·5% Extens.	Limit of Proportionality			
R1	1·73	0·14	0·04	9·5	6·0	—	—	9	14
R2	2·15	1·17	0·06	11·9	6·2	1·0	7,500	11	20
R3	2·54	0·78	0·13	14·2	7·0	—	—	16	22
R4	1·39	1·98	0·07	14·4	6·6	2·4	6,300	17	21
R5	3·43	1·04	0·04	21·8	8·2	2·0	7,800	25	14
"Everdur"	1·67	5·30	0·10	15·0	7·8	2·8	6,200	20	25
R7	3·22	2·01	0·08	13·3	6·6	2·6	7,900	13	18
R8	1·14	1·30	0·07	21·1	8·1	2·0	6,700	15	14
R9	2·29	4·49	0·12	15·5	9·4	3·6	8,200	15	21
R10	5·35	1·45	0·12	18·5	15·9	5·6	6,200	1	1
R11	5·85	1·58	0·17	18·8	—	11·2	6,800	1	0
R12	4·74	3·19	0·12	21·6	14·0	3·6	6,800	1	6
Plain silicon-copper alloys	3·0	See Tables I. and II.		14·9	7·6	2·6	5,600	24	41
	4·5			18·1	11·2	—	10,700	11	15
	6·5			14·5	—	—	—	0	0
Everdur makers' tests (cf. R5 above)...				22·1	13·4	—	—	24	35

With one or two exceptions, due to unsoundness, each result given above is the mean of tests upon two samples machined from the same casting.

* As this figure may not represent stress for 0·5% extension it is scarcely comparative.

Hardness tests applied to certain specimens prepared from strip ingots, are noted that the strip ingots are about 20 Brinell higher than the bars of the same the more severe strip ingots accord greater hardness noted that silicon influence upon than manganese hardness tests performed, using hammer, upon specimens, and which follow the as the Brinell included in Table the Brinell figures marked discrepancy the values for the and strip ingots.

Test-pieces were machined from the strip ingots and subjected to the Izod not upon a 120 ft.-lb. machine, the specimens being of standard dimensions—namely, section, notch 2 mm. deep at an angle of 45°, with circular bottom of 0·25 mm. radius, were 28 mm. from the ends of the specimen to be struck. The results of these tests in Table VII, from which it may be concluded that, in the chill-cast state, silicon-manganese alloys of about the composition 3·5% silicon and 1% manganese had the best all-round properties of any between the limits of 0 to 5% each of silicon and manganese.

Table VII.—The Hardness and Impact Value of Cast Silicon-Manganese-Copper Alloy.

Reference Mark in Order of Descending Copper Content.	Chemical Composition, %.			Hardness Numbers		Round Bars.					Strip Ingots.				
	Si	Mn	Fe	Brinell	Sclerometer	Reference Mark in Order of Descending Copper Content.	Chemical Composition, %.	Si	Mn	Fe	Brinell	Sclerometer	Izod Impact on a		
R1	1·73	0·44	0·04	62	7	S1	1·50	0·54	0·09	68	8				
R2	2·15	1·17	0·06	63	8	S2	2·27	1·08	0·10	72	10	45 (umb)			
R3	2·52	0·78	0·13	67	10	S3	1·99	1·43	0·11	68	8	47			
R4	1·39	1·98	0·07	70	10	S4	1·51	2·26	0·03	74	9	50			
R5	3·43	1·04	0·04	95	15	S5	3·17	0·99	0·10	116	16	51			
R6	1·67	3·20	0·10	65	9	S6	3·27	1·82	0·12	86	15				
R7	3·22	2·01	0·08	72	15	S7	4·14	1·51	0·09	113	21	22 (umb)			
R8	4·14	1·30	0·07	92	17	S8	3·74	2·01	0·08	113	119	19			
R9	3·29	4·49	0·12	76	9	S9	2·40	3·53	0·09	86	10	12 (umb)			
R10	5·35	1·40	0·12	148	27	S10	5·42	2·72	0·08	99	16	26 (umb)			
R11	5·85	1·58	0·17	214	37	S11	5·30	1·21	0·16	108	36	2			
R12	4·74	3·19	0·12	133	17	S12	2·00	3·56	0·12	109	(18)	28			
Plain silicon copper alloys	3·0	See Table II.		71	—	Everdur No. 5 Metal	3·3	1	—	—	—	13-14	Makers with		
	4·5			100	—										

Each result is the mean of several tests.

Iron-Copper Alloys—contd.

h that of good ultimate value—namely, 90 to properties occur.

In the presence of excessive

ness tests were also made to certain of the Izod bars prepared from the ingots, and it will be seen that the values of the ingots are in general higher than the 20 Brinell numbers than those from round bars of the same composition, the severe chilling of the ingots accounting for the lower hardness. It will be seen that silicon has more effect upon the hardness of manganese. Sclerometer tests were also performed using the universal sclerometer, and the results follow the general trend of Brinell numbers. These numbers are given in Table VII. Unlike the Brinell figures, there is no appreciable discrepancy between the values for the round bars and the ingots.

Izod notched-bar test, namely, 1 cm. x 1 cm. x 1 cm. radius. The notches for these tests are included in the silicon-manganese-copper sheet and all-round mechanical properties.

Iron-Copper Alloys.

Izod Impact Value in Ft.-lb. on a 120 ft.-lb. Machine.		
	As Cast.	Annealed.
45 (unbroken)	44 (unbroken)	—
47	44	—
50	45	—
51	54	—
22 (broken)	53 (unbroken)	—
19	49	—
42 (unbroken)	53	—
26 (broken)	56	—
2	14 (broken)	—
28	23	—

Makers' tests; compare with R5, R7, S5, S6.

PRODUCTION OF SILICON-MANGANESE-COPPER SHEET.

Of the twelve strip ingots cast, six were selected for cold rolling and six for hot rolling, according to the following division:

For cold rolling	S1 ..	S2 ..	S4 ..	S6 ..	S7 ..	S9
For hot rolling	S3 ..	S5 ..	S8 ..	S10 ..	S11 ..	S12

With the exception of S7, which contains 5.14% silicon with 1.51% manganese, good sheet was obtained by cold-rolling all six ingots. The initial temperature for the hot rolling was $750^{\circ} \pm 20^{\circ}$ C. and, for the most part, the ingots rolled well as long as the temperature was maintained fairly high, but on cooling off serious cracking took place at the edges. Nevertheless, hot rolling can be said to give better results than cold, for the alloys relatively high in silicon, provided the temperature is maintained above redness. Care must be taken not to exceed a temperature of 800° C. or the material becomes hot short.

PROPERTIES OF SILICON-MANGANESE-COPPER SHEET.

The results of tensile tests taken from each specimen of sheet in every condition are collected in Table VIII., in which each figure is the selected means of three independent tests. An examination

Table VIII.—The Tensile Properties of Silicon-Manganese-Copper Sheet.

Reference Mark.	Composition, %			Hard Bright, Cold-Work, 33% ^a			Soft Bright, Cold-Work, 11% ^a			Hot-Rolled, Cold-Work, Indefinite			Annealed, Cold-Work, Nil.						
	Si	Mn	Fe	Longitudinal, Break. Elong.	Transverse, Break. Elong.	Longitudinal, Break. Elong.	Transverse, Break. Elong.	Longitudinal, Break. Elong.	Transverse, Break. Elong.	Longitudinal, Break. Elong.	Transverse, Break. Elong.	Longitudinal, Break. Elong.	Transverse, Break. Elong.	Longitudinal, Break. Elong.					
S1	1.50	0.54	0.09	29.4	17	18.6	4	24.2	38	22.0	8	—	—	16.8	34	14.3	24		
S2	2.37	1.08	0.10	33.9	20	33.7	5	26.3	42	23.3	12	—	—	19.7	74	15.0	49		
S3	1.99	1.45	0.11	—	—	—	—	22.3	39	22.4	32	28.5	15	22.3	16	16.6	60	16.9	45
S4	1.31	2.26	0.09	35.5	15	37.3	13	27.9	34	29.0	17	—	—	18.0	50	17.7	34		
S5	3.17	0.99	0.10	—	—	—	—	34.4	36	35.1	22	44.4	16	44.5	9	24.6	68	23.1	53
S6	3.27	1.82	0.12	41.4	29	44.4	9	31.6	40	29.0	7	—	—	—	—	24.3	74	22.8	53
S7	4.14	1.51	0.09	45.5	15	42.5	7	37.6	39	36.2	12	—	—	—	—	27.3	53	25.0	42
S8	3.71	2.01	0.08	—	—	—	—	39.4	40	39.7	27	49.7	18	44.1	14	25.1	54	25.2	54
S9	2.40	3.53	0.09	41.6	19	40.3	12	32.4	28	31.0	18	—	—	—	—	22.6	74	19.1	43
S10	3.42	2.72	0.08	—	—	—	—	38.5	32	38.6	29	45.2	16	45.3	8	26.0	62	26.4	52
S11	5.30	1.21	0.16	—	—	—	—	—	—	—	—	—	—	—	—	30.0	19	31.4	10
S12	2.60	5.56	0.12	—	—	—	—	38.3	24	41.1	21	44.2	19	41.9	16	29.5	29	28.9	21
At 50% cold-work																			
See Table IV	2.51	0.0	0.26	—	—	—	—	—	—	—	—	24.3	72.1	25.1	46	22.7	72	23.3	62
Table IV	3.23	0.0	0.29	48.5	10	18.0	5	—	—	—	—	—	—	—	—	29.7	64	26.9	31
	4.58	0.0	0.28	—	—	—	—	—	—	—	—	38.6	14	39.8	6	33.0	33	32.6	17

Longitudinal and transverse relative to direction of rolling.

Breaking strength in tons/sq. in.

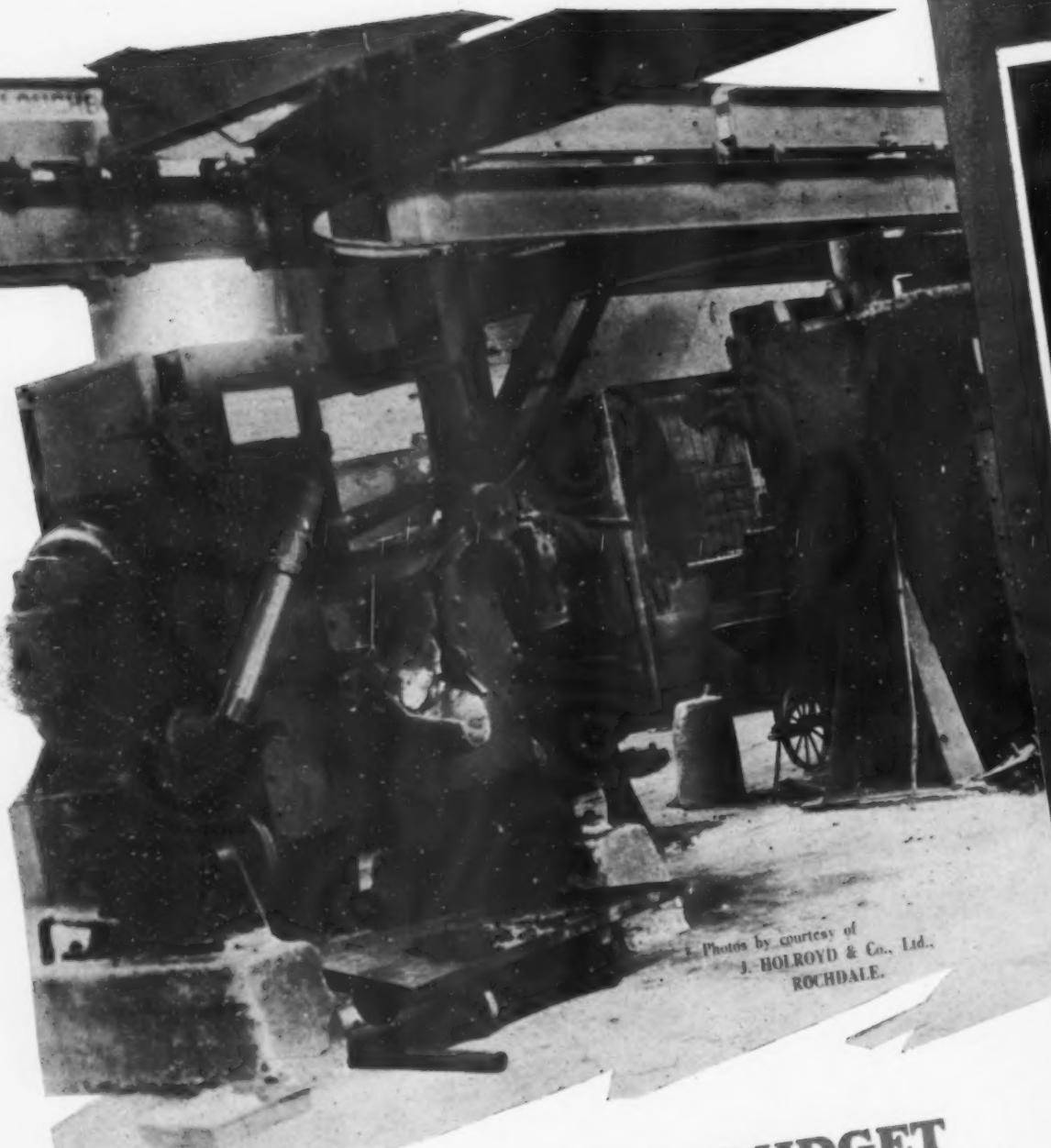
Elongation % on 4" area.

of the table reveals the fact that the ductility, and in many cases the strength also, is lower when tested across than along the direction of rolling. The results show definitely that hot rolling (especially with cross rolling), followed by cold rolling, imparts good strength without the introduction of objectionable directional properties. Such procedure is therefore recommended; it gives greater fuel and mill-power economy, as well as a better product than cold rolling with intermediate anneals.

OXIDATION OF SILICON-COPPER AND SILICON-MANGANESE-COPPER ALLOYS AT HIGH TEMPERATURES.

Careful experiments were carried out to test the resistance of these alloys to oxidation at a temperature of 725° C., and the main conclusions drawn from the results indicate that the scale formed on silicon-copper alloys resembled that ordinarily formed on copper, in so far as it consisted of a black cupric oxide layer superimposed upon a firmly adherent cuprous oxide film. The resistance of silicon-copper alloys to high temperature oxidation, about 700° C., increases with the silicon content. At 725° C. the rate of oxidation of an alloy containing 4.58% silicon was from one-quarter to one-seventh that of copper. The adherence of the outer layer of black oxide was also a function of the silicon content. At temperatures above 800° C. the oxidation rate increases, and approximates to that of pure copper.

The addition of 1% of manganese to a 4% silicon alloy did not appreciably alter the rate of oxidation, but rendered the black oxide much less adherent.



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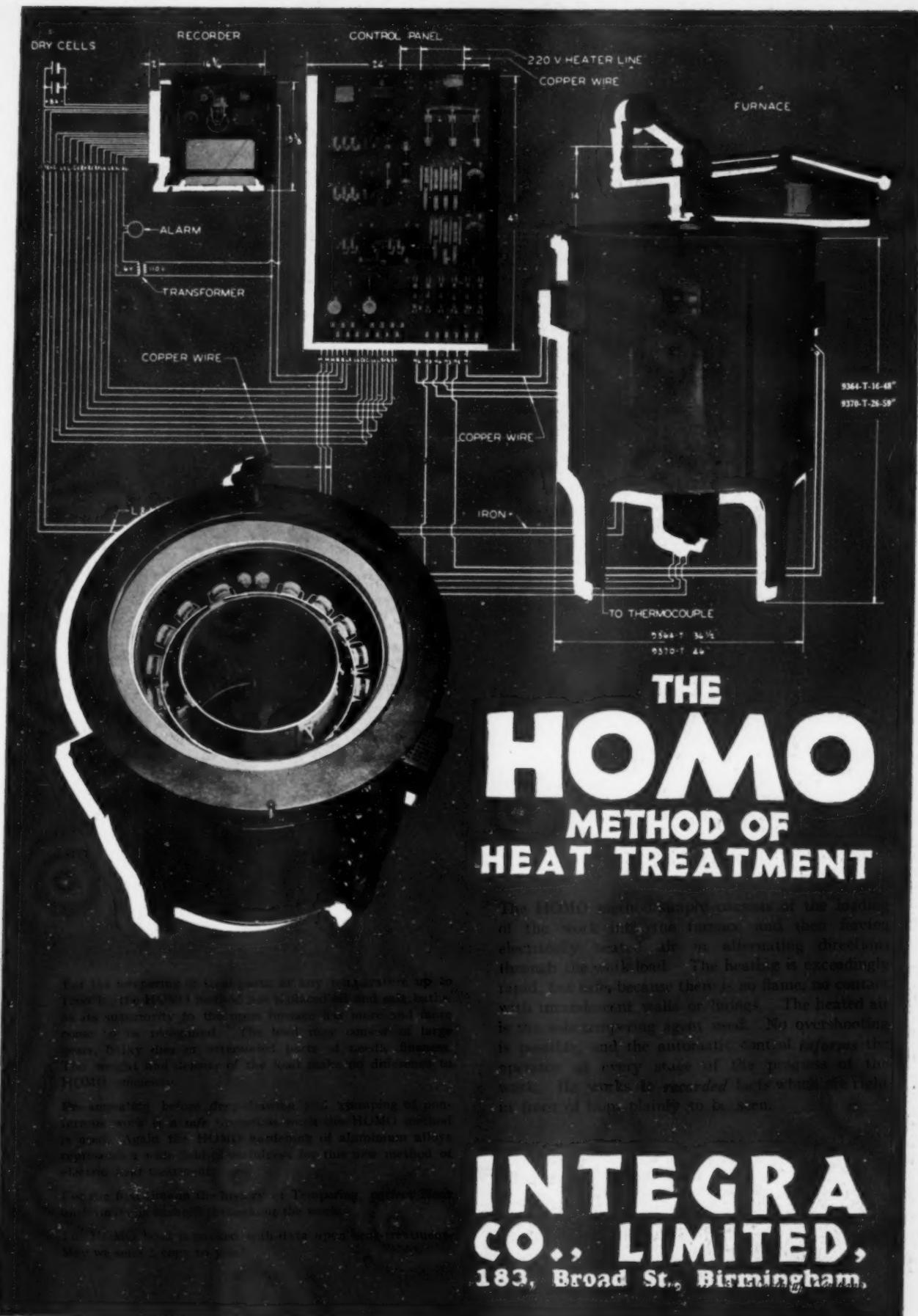
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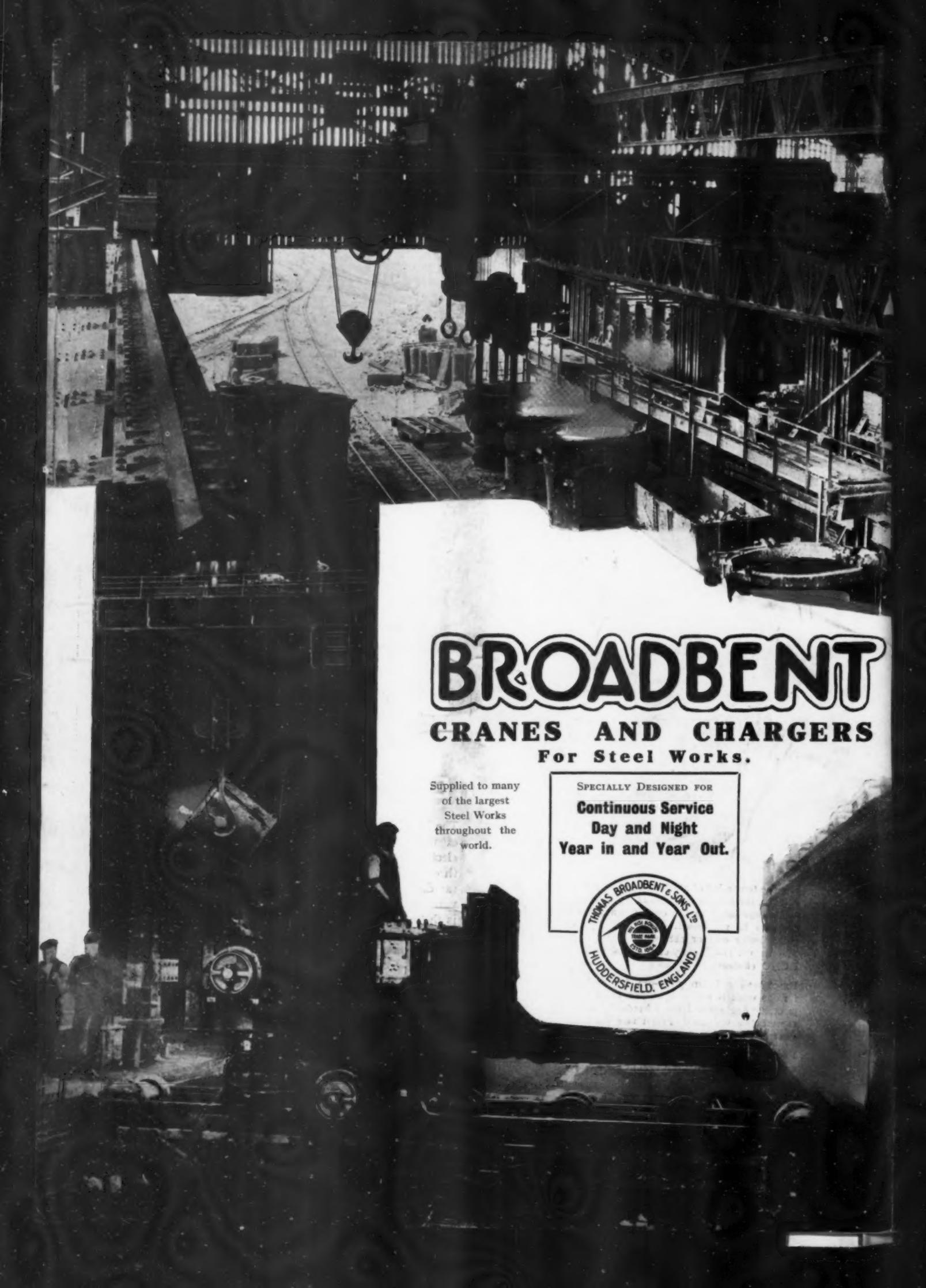
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